XXI. *On the Anatomy and Physiology of the Nematoids, Parasitic and Free; with observations on their Zoological Position and Affinities to the Echinoderms.* By H. CHARLTON BASTIAN, *M.A., M.B. Lond., F.L.S.*

Received June 13,—Read June 15, 1865.

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ALTHOUGH the parasitic Nematoids have been so long known and frequently submitted to anatomical examination, it is somewhat surprising that, even up to within quite a recent period, nothing was certainly known with regard to the arrangement in them of the nervous system, or as to whether they possessed any modification of the organs of circulation. The existence of both these systems has been asserted and denied over and over again by successive observers, and conflicting statements in this particular field of research have been so rife, that a well-known writer*, recently alluding to this subject, even goes so far as to state that the many discrepancies in the accounts given by leading Helminthologists of Nematoid anatomy "tend to throw great doubt upon the general value of histological observations among the Helminths." Although far from sharing in this opinion, I must admit that the tangled network of opposing statements is sufficiently disheartening.

As a necessary consequence of our deficient knowledge of the real anatomy of these animals, this order *Nematoidea* has been a continual stumbling-block in the path of the philosophic zoologist. What is their place in the animal kingdom? A question, surely, impossible to answer whilst so many doubts hung over the question of the arrangement of their nervous and circulatory organs; and it seems to me that many of the erroneous opinions which have been held concerning these parts may be traced to

* Dr. COBBOLD, 'Entozoa: an Introduction to the Study of Helminthology,' 1864, p. 363.

the influence of somewhat hasty and superficial views regarding the affinities of these animals, leavened too powerfully by a consideration of their mere worm-like external form. Moreover, the confusion has been heightened by the presence in the Nematoids of rather anomalous structures—the so-called "lateral and median lines"—which, though themselves neither vessels nor nerves, have, each in turn, been taken for both by different observers. The intimate connexion and blending of the real nervous system with these bodies in one part of their length, and its limited extent, account in a measure for its having so long escaped detection, since this system cannot possibly be properly examined without most careful dissection and after-preparation of the specimen.

Having become accidentally interested in the anatomy of the Nematoids, and having then been made fully aware of the unsatisfactory state of our knowledge concerning them, I felt a strong desire to be able to remove some of the existing difficulties, so as to place the subject upon a somewhat firmer foundation, and to discover what were the real affinities of these animals. In addition to the present memoir, this desire has resulted in the discovery and description* of 100 new species of free Nematoids, partly marine and partly freshwater; and my researches on this branch of the subject have convinced me that these may be considered to constitute one of the most numerous and widely distributed families in the whole animal kingdom, yielding in this respect, perhaps, only to the ubiquitous Diatomaceæ in the vegetable world. Their bodies are so transparent, and enticing for microscopical examination, that I was tempted on and on, far beyond the limits I had originally intended, in the hopes of being able to learn something from them concerning the moot points in Nematoid anatomy. But although many interesting facts have been thus acquired, still more have been gathered from my later investigations into the structure of the parasitic Nematoids—though, fortunately, the two sets of observations mutually throw light on one another.

The recognition of the great numerical abundance and wide distribution of these free Nematoids tends to throw much additional interest over the order *Nematoidea*, and make the Nematoids as a group quite unique among other animals; for in them we see a great assemblage, one division of which has long been known to constitute a section of the class Entozoa, most remarkable for the number of its representatives and the frequency with which they are met in the most varied organs of animals belonging to every grade from the Acalephæ upwards; whilst the other is now, also, known to be composed of animals, in all probability infinitely more numerous still, leading a free and independent life in all stages of their existence, tenanting almost every variety of natural external habitat where moisture exists, and even invading in some cases, as parasites, representatives of the vegetable kingdom. Yet, strange to say, the organization of these latter animals, as a whole, differs in no very obvious or important manner from that of their parasitic kindred. In accordance with their requirements, the sense-organs in many of the free Nematoids become more numerous, and other modifications obtain; still, so far as we have yet been able to ascertain, their essential structure is not materially

* Monograph on the Anguillulidæ or Free Nematoids, Trans. of Linn. Soc. vol. xxv. p. 72.

modified, and the nature of the alterations encountered tends only to ally them more closely by organization as well as habitat to the members of the class Echinodermata.

The remarkable tenacity of life, and power of resuming all their vital manifestations after the most prolonged period of desiccation and torpidity, possessed by some of the free Nematoids, in common with the *Rotifera*, make them objects of extreme interest to the biologist, which interest, certainly, suffers no diminution from the fact that, so far as I have observed, this extraordinary attribute is possessed only by members of the four land and freshwater genera, *Tylenchus*, *Aphelenchus*, *Plectus*, and *Cephalobus*, whilst other representatives of the family are frail, and unable to recover even after the shortest periods of desiccation.

My observations on the anatomy of the parasitic Nematoids have been conducted more or less fully upon twenty-six species, some of which belong to each of the seven sections into which DUJARDIN * divided the order, though I have studied most completely seven species of the genus *Ascaris*, and of these especially *Ascaris lumbricoides* and *A. megalocephala*. In many important particulars these observations are in accordance with the results of the recent researches of Drs. SCHNEIDER and EBERTH in Germany, whose investigations have done so much to improve the state of our knowledge concerning the organization of these animals; though, as will be seen under the various subdivisions, there are many other points upon which I have been unable to reconcile my observations with those of either one or both of these anatomists. Although, therefore, difficulties and some disagreements still remain, yet I hope to be able to remove many which have hitherto obscured this subject, and to offer suggestions which, if accepted, will go far to solve the question of the zoological affinities of the Nematoids.

TEGUMENTARY ORGANS AND APPENDAGES.

Many misconceptions have prevailed concerning the nature of the integument in the Nematoids, as I have already pointed out in the paper "On the Structure and Nature of the *Dracunculus*" †. It has been described by Von SIEBOLD ‡, DUJARDIN §, OWEN ||, and most other anatomists, as divisible into two main portions—a structureless epidermis composed of chitine, and a corium made up of layers of longitudinal and oblique decussating fibres. And, although in this communication I pointed out the fact that these so-called fibrous layers, or membranes, were not such in reality, but that, in common with the external more homogeneous layer, they were essentially epidermic in nature, consisting of chitinous lamellæ presenting various kinds of markings, and, in all probability, were excreted from some deep cellular layer, still, I had not at that time been able actually to recognize the existence of such a layer in the Nematoids. Since then I have fully satisfied myself of the existence of a distinct, deep, cellulo-granular

* Histoire Naturelle des Helminthes, 1845, p. 2.

† Trans. of Linn. Soc. vol. xxiv. p. 108.

‡ Manuel d'Anat. Comp. Trad. Française, 1850, p. 115.

§ Hist. Nat. des Helminthes, 1845.

|| Lect. on Comp. Anat. 2nd edit. 1855, p. 99.

layer from which the chitinous lamellæ are excreted, and which corresponds most likely with what Dr. COBBOLD describes as a 'homogeneous' granular layer*.

As a result of my recent investigations I can now make the following statements. The integument of all the Nematoids examined appeared to be composed essentially of two portions, an external, or 'ecderon,' varying much in different genera, though composed essentially of an uncertain number of layers of a colourless chitinous material, the outermost of which often presented markings, regular or irregular, on its surface; and an 'enderon,' or internal, active, formative portion, consisting of a cellular layer bounded on both sides by a loose fibrous membrane, uniting it externally with the epidermic layers, and internally with the muscles. In the intermuscular intervals, and especially in the lateral, this layer is much thickened, and projects between the muscles into the general cavity of the body so as to constitute the well-known, though much misunderstood, 'lateral and median lines' (Plate XXIII. fig. 1), concerning the nature of which so many conflicting statements have been made. The median lines are by no means so common as they seem to have been considered; in many Nematoids no traces of them exist, and since the lateral lines often contain an axial longitudinal vessel, I shall defer the further consideration of these developments of the deep cellular layer until I come to speak of the organs of circulation and the so-called 'water-vascular system.'

I have examined the integument most carefully in *Dracunculus medinensis*, and also in *Ascaris lumbricoides* and *A. megalocephala*, and in these last two animals have found it similar in almost all respects. In them its total thickness, as measured in transverse sections, is about $\frac{1}{125}''$; rather more than one-fifth of which is due to the thickness of the cellular layer, whilst the remaining portion is made up of the several chitinous lamellæ. The distinct recognition of this inner layer as something else than a mere granular membrane, and its absolute continuity with the lateral and median lines, is a matter of no small importance for the proper elucidation of Nematoid anatomy; and this layer also deserves our attention, since it seems to take an active share in the development as well as in the vital functions of these animals. It is not only the formative layer of the thick chitinous envelope, but, in all probability, it takes a most active part in the respiratory processes, since it communicates directly with the exterior, and contains within its substance the principal representatives of the vascular system of the Nematoids. In the *Ascarides* generally it is well developed, and is distinct also in the Guineaworm† and in *Spiroptera obtusa*, but it was found to be very thin in a species of *Filaria* and in *Prosthecosacter inflexus*.

In transverse sections of *Ascaris lumbricoides* or *A. megalocephala*, the direct continuity and similarity of tissue between this layer and the lateral and median prominences can be easily seen (Plate XXIII. figs. 5 & 16). After a portion of the body has been slit

* *Loc. cit.* p. 380.

† This, which I was unable satisfactorily to demonstrate before, I have lately been able to make out, together with a few other additional facts, after the examination of some specimens in excellent preservation kindly given to me by Professor AITKEN.

open and the longitudinal muscles have been stripped off, at first sight there appears nothing more than a mere granular layer situated on the external chitinous integument, the granules themselves consisting of rather large, highly refractive particles. But a more careful inspection reveals a number of larger ovoid or spherical cells about $\frac{1}{1250}''$ in diameter, and provided with a distinct nucleus (Plate XXII. figs. 13 & 14) scattered amongst the granules; and indeed it seems highly probable that most of this granular matter is either now contained in cells, or may be considered as the remains of cell formation*.

A very few fibres appear to interlace amongst this material, though these are almost wholly collected into two distinct layers, the fibres in which have different directions, and are aggregated together so as to form a loose meshwork or fibrous membrane. The external and thinner of the two connects the cellulo-granular layer with the chitinous envelope, and its very delicate fibres have a transverse direction; whilst the internal membrane, made up of stronger fibres having for the most part a longitudinal direction, serves as an aponeurosis for the firm attachment of the great longitudinal muscles, and in the intermuscular intervals it constitutes the bounding membrane of the lateral and median lines.

The chitinous lamellæ are plainly divisible into five distinct primary layers, the most internal of which is the thinnest, and presents very faint, close-set, longitudinal markings (Plate XXIII. figs. 5, *e*, & 15). It seems rather more adherent to the enderon than to the next chitinous layer, and is often removed with the former when the integument is torn with needles. I have found nothing answering to this layer in *Dracunculus*. The next two layers are much thicker, though equal to one another, and similar in all respects, save that their oblique markings are in opposite directions (Plate XXIII. figs. 5, *d*, *c*, & 14). These layers can be split into a variable number of lamellæ, though not nearly with so much facility as the similar layers in the Guineaworm, which in this latter animal have also a greater proportional thickness. The markings (of the two layers) appear as bright lines whose directions intersect one another, at very acute angles, in different planes. The next layer, which is the thickest of all (Plate XXIII. fig. 5, *b*), seems absolutely homogeneous and without markings of any kind. This I have never been able to isolate from the adjoining layers, though it and the others, with their respective proportions, may be readily seen in thin transverse sections of a dried animal made with a sharp razor and subsequently mounted in acetic acid†. Examined with the polariscope and a selenite plate, the whole structure becomes still more distinct—the contiguous layers

* Eberth (Untersuch. über Nemat. p. 46) seems to have recognized this structure as composed of delicate cells in the *Trichocephalidæ*, though he speaks of it as beneath the skin instead of forming one of its most important layers: he says, "Dicht unter der Haut trifft man eine zarte feinkörnige Schicht, die mir aus sehr zarten Zellen zu bestehen scheint."

† After making sections of the Nematoids, whether fresh or dry, I always place them in acetic acid previous to examination; it not only renders them more transparent, but, owing to the rapid imbibition of the fluid, it is the best means of restoring the circular form of the section. If the specimen is to be preserved, it should be soon taken out of the acetic acid and mounted in glycerine.

being accurately distinguished by bright and contrasting bands of colour. The external layer, like the last, does not seem capable of being split into thinner lamellæ, and though not so thick as this, is thicker than either of the others. It presents well-marked, broad, double contoured transverse lines (Plate XXIII. fig. 13). These are about $\frac{1}{1500}''$ apart, and mostly preserve a considerable parallelism with one another, except where it is disturbed by the bifurcation or commencement of one of the lines, as shown in the figure. They do not all therefore form perfect circles round the body, and differ from the corresponding markings in the Guineaworm by their altogether more regular arrangement and the greater number of these bifurcations*.

Whatever the nature of the alteration in the chitinous substance may be, giving rise to these markings, it seems to extend through the whole thickness of this outermost layer, and is doubtless a change similar to that causing the markings, not only of the other layers, but also of the chitinous lamellæ in the Nematoids generally. This change causes an alteration in the refractive power of the lamella; and in some instances, at least, I think there is evidence to show that this is due merely to an alteration in the thickness of the membrane, as seems certainly to be the case with the irregular markings of the integument in *Prosthecosacter inflexus.* In transverse section the lines are seen to correspond to actual ridges of the integument (Plate XXVII. figs. 4 & 5). In other cases, however, it may perhaps depend upon a mere alteration in density of the lamella in the situation of the lines, or even upon a diminution in thickness. The number and arrangement of the chitinous layers, and also the character of their markings, varies somewhat even in the different species of the genus *Ascaris*, and to a considerable extent in the Nematoids generally. The markings of the external layer, however, seem to afford a pretty constant generic character. In *Ascaris mystax*, where I have looked for it particularly, I have been unable to recognize the thin inner layer with the longitudinal markings. In transverse sections of the integument of *A. marginata*, a number of fine lines may be seen radiating outwards from the inner layers (Plate XXVI. fig. 1); these are remarkably numerous in this species, though they may be seen more distinctly owing to their increased size (especially in the lateral regions) in *A. lumbricoides* and *A. megalocephala*, extending from a slightly swollen base through the two outer layers. There seems to be no reason to believe that they are tubular, and they may be mere connecting perforating fibres. In *A. spiculigera*, in the intervals between the transverse surface lines, there are series of short connecting markings at right angles to them (Plate XXVI. fig. 17); whilst in a deeper layer, between the external one and those with oblique markings, are somewhat diamond-shaped markings, arranged in transverse series, and the same distance apart as the external circular lines†. In the genus *Strongylus* the most pronounced external markings are longitudinal, though these are intersected by very delicate transverse ones.

* These markings must not be confounded with the apparent circular markings seen by the naked eye, which are due as it were to wrinkling of the integument, and between any two of which would be included from thirty to seventy of the circular lines described above.

† These are referred to by DUJARDIN as "*des séries assez régulières de lacunes.*"—Loc. cit. p. 206.

This I have seen most plainly in individuals from the stomach of a hare (Plate XXVII. fig. 10), though I have recognized a similar arrangement less distinctly in *S. filaria* and *S. auricularis*. In *Trichocephalus affinis*, in place of the two layers with oblique intersecting lines, there is a single layer with transverse lines of a similar character, though quite different from the more pronounced markings of the surface layer. In a species of *Filaria* examined, I could detect only a thin external layer with transverse markings, and a thick structureless portion, apparently devoid of markings, intervening between it and the very thin cellular layer; whilst in *Prosthecosacter inflexus* only one structureless and very transparent glass-like epidermic layer exists, which being developed into ridges in an irregular manner upon its surface, causes it to exhibit a similar arrangement of lines or integumental markings when seen by transmitted light (Plate XXVII. figs. 4 & 7). In this animal also the deep skin layer is remarkably thin.

The integument of the free Nematoids is evidently formed upon the same type, but I have distinctly recognized oblique intersecting lines in the internal layers of *Dorylaimus stagnalis* only. Dujardin has also represented these. In this animal there are no transverse markings of the external layer, but well-marked longitudinal ones. The representatives of other genera, such as *Enoplus* and *Chromadora*, present both transverse and longitudinal lines, the former being most pronounced in the genus *Chromadora* and the latter in *Enoplus*; whilst in *Plectus*, *Trilobus*, and many other genera transverse markings only are seen.

In the genera *Cyatholaimus* and *Spilophora* we meet with circular rows of dots instead of lines, and in several genera, such as *Leptosomatum*, *Phanoderma*, &c., no integumental markings whatever can be recognized. The cellular enderon I have not detected in these animals*, except as it exists in the lateral regions of the body, where it constitutes the lateral bands. These animals are so small that the difficulty of making satisfactory transverse sections has hitherto been insuperable.

In both the parasitic and the free Nematoids the chitinous portion of the integument is occasionally developed into alæ or other projections; these are cervical in *Ascaris mystax*, and principally composed of a development of what is generally the thickest layer, viz., the second from without inwards. But these developments more commonly exist as caudal expansions in the male, such as are so well known in the genera *Strongylus* and *Spiroptera* amongst the parasitic species. Structures of a similar nature may be seen amongst the free Nematoids in the genus *Rhabditis*, where the lateral alæ are supported by sets of delicate rays†, and in *Tylenchus*, where they are less developed and unsupported by such processes‡.

The development of the external layers of the integument into spines is not an unfrequent occurrence amongst the parasitic Nematoids; these are somewhat conical

* Unless, as seems most probable, the almost superficial cells met with in many species of the genus *Cyatholaimus* (Plate XXVIII. fig. 36), giving them their characteristic maculated appearance, do in reality belong to this layer.

† Trans. of Linn. Soc. vol. xxv. pl. 10, fig. 62.

‡ Ibid. pl. 10, fig. 114.

and thickly arranged in transverse rows in *A. echinata*; exist as an innumerable quantity of recurved hooks on the anterior part of the body of a species of *Spiroptera* found by Mr. BELLINGHAM in *Anas tadorna*; as circular groups of palmate spines in *Gnathostoma spinigerum* *; and as acute recurved spines arranged in a quincunxial manner on the anterior part of the body of *Hystrichis tricolor*. In *Trichosomum tomentosum*, DUJARDIN found a portion of the body clothed with a multitude of very minute, spreading, hair-like processes. Amongst the free Nematoids, and more particularly the marine species, hair-like processes or setæ are very abundant, existing principally as circlets round the head, and in linear series on the ventral region of the caudal extremity of many males. They are often scattered more sparingly over other parts of the body, and altogether seem to reach their maximum development, so far as I have observed, in *Sphærolaimus hirsutus* †. These setæ of the free Nematoids seem to take the place of the spines in the parasitic species, as the latter structures are not met with in either marine, land, or freshwater representatives.

Papillæ and Suckers.—These organs, either separate or combined, are of very common occurrence in connexion with the integument, both among parasitic and free Nematoids. They exist in two principal situations—around the head, and about the caudal extremity of many males. Some of the organs met with in the latter situation are undoubtedly suckers, though with regard to other structures, both in this region and around the mouth, it seems by no means clear whether they should be considered simply as papillæ, or whether they are also suctorial.

The cephalic papillæ can be well studied in *Ascaris lumbricoides*, though their number and arrangement appear to be nearly the same in all the species of this genus. Two exist on the dorsal head lobe (one on each side), and one in the middle of each latero-ventral lobe (Plate XXII. figs. 14 & 19). In *A. lumbricoides* they present the following structure; externally there is a convex projection of the chitinous envelope with a minute perforation in its centre, running down to a depression in the apex of a well-marked, bluntly conical projection of the deep cellular layer (Plate XXII. fig. 17), which with some fibres (mainly nerves ?) constitutes the central parts of these lobes ‡. These latter are essentially skin development formed around and enclosing the triradiate mouth, and do not contain well-marked prolongations of the great longitudinal muscles as stated by KÜCHENMEISTER. The papillæ which they bear, therefore, may be simple tactile organs, or they may be partly suctorial. In *Spiroptera obtusa* there are six cephalic lobes, each of which bears a single papilla. Well-developed papillæ exist around the mouth in the genera *Cucullanus* and *Sclerostomum*, and more simple ones in the genera *Dracunculus* and *Filaria*. Amongst the free Nematoids they are best developed in the genus *Enoplus*. I cannot say, however, whether the cephalic papillæ are perforated in the same way in the members of these other genera as I have found them to be in those of *Ascaris*.

* DIESING's *Cheiracanthus robustus*.

† Trans. of Linn. Soc. vol. xxv. pl. 13, fig 192.

‡ "Cock's-comb-like structures."—KÜCHENMEISTER (Syd. Soc. Transl.), p. 411.

Papillæ agreeing in all respects with those described above, save that the external aperture is oftener in the centre of a slightly concave depression rather than of a convex eminence, are met with in single or double series in the ventral region, above the ano-genital aperture of male *Ascarides*. In *A. lumbricoides*, on the posterior part of the body, for a length of $1\frac{1}{2}''$ there are about forty of these papillæ on each side of the ventral region (Plate XXII. fig. 20). The anterior ones, gradually diverging more to the lateral aspect of the body, are in single file and about $\frac{1}{6}''$ apart, but posteriorly they are closer together and the linear arrangement is not preserved. These papillæ may be well seen in transverse sections (Plate XXIII. figs. 3 & 4, *l*, *l*). I have seen well-marked suctorial papillæ also in the males of *Heterakis acuminata* (Plate XXII. fig. 13) and *Oxyuris vermicularis*; and besides bodies of this nature, in *Cucullanus heterochrous* there is also a very large and prominent sucker-like body in the mid-ventral region. In the same situation, a large and peculiar body of a similar nature is found in *Heterakis vesicularis**. In short, structures of this nature seem much more commonly present than absent in the males of parasitic Nematoids, whilst in the free species the reverse condition appears to obtain. Such bodies are, nevertheless, well developed in the genus *Leptosomatum*†, whilst a series of integumental channels variable in number exist in the same region of most *Dorylaimi*. The bodies which I have called "supplemental organs" existing in the males of the genera *Enoplus*, *Phanoderma*, and *Anticoma*, seem altogether problematical in their nature‡.

In the free Nematoids we meet with an organ fully in harmony with the requirements of these animals, but which, from their different mode of life, neither exists nor is needed in the parasitic species. I allude to the terminal tail-sucker which is found in both sexes in nearly all the marine species, and in those of about half the land and freshwater genera. It is the only kind of organ of prehension with which these minute animals are provided, and is rendered all the more necessary by the smooth and polished nature of their integuments. It is most constant, too, and best developed just in those species which require it most—in those living amongst the sand and stones of the sea-shore, in its surface-mud, or tenanting the fine weeds in its rock pools, which day by day are exposed to the ever-moving currents raised by wind and tide, and which would be continually swept from their natural haunts were they not provided with some means of attaching themselves to surrounding objects. In its simplest form, such as we find it in the members of the freshwater genus *Mononchus*, all we can recognize is a very slight roundness and increase of size in the narrow terminal extremity, with a central aperture; but where it is more developed, as in the genus *Enoplus*, or *Leptosomatum*, in addition to the terminal extremity being slightly swollen, we see the terminal aperture continued inwards as a canal, and terminating after a short distance at a more solid though perforated portion, to which are attached three pyriform sacs or elongated tubes§. In the genus *Enoplus* these sacs occupy the cavity of the body posterior to the

* Würzb. Naturwiss. Zeitsch. Erst. Bd. 1860, Taf. ii. 2 (Eberth).

† Trans. of Linn. Soc. vol. xxv. pl. 12, fig. 163. ‡ See figures, *loc. cit.* § See figures, *loc. cit.*

anus, and are of an elongated pyriform shape; whilst in other species, as may be well seen in *Oncholaimus vulgaris* and in the *Leptosomata*, they are still more elongated and tubular in form, and extend for some distance into the cavity of the body by the side of the intestine. These appendages only exist in species having otherwise large and well-developed suckers, and their main function seems to me most likely to be connected with the more efficient action of these structures. According to the views of LEYDIG and EBERTH *, these sacs are "tail-glands" (Schwanzdrüse) opening by a terminal "papilla", and secreting a clear gummy substance, which enables them to adhere to surrounding objects. I do not think this mechanism of adhesion a very probable one; and although in a specimen of *Oncholaimus vulgaris* I have seen expelled from these bodies through the terminal orifice, at irregular intervals, small quantities of fluid rendered apparent by the minute molecules suspended in it, still their generally clear appearance, and the absence of all the main characters belonging to glandular structures in other parts of the body, lead me rather to discountenance this view of their nature. Instead of "glands" I would term them *sucker-tubes*, believing them to be contractile in their nature and mainly destined to perfect the action of the sucker, which seems to operate by the ordinary principles of hydrostatic pressure, rather than by the adhesive properties of gummy secretions.

Integumental pores.—In *Dorylaimus stagnalis* I first detected a number of minute channels through the integument, and though I have since recognized these in many other free Nematoids (especially in the larger marine species), in no animal can they be so well observed as that in which they were first discovered. The thickness of the integument, and the number of the pores in the lateral regions of the body of this animal, are the reasons which make it so suitable for examination. They seem to be very numerous over those portions of the lateral regions of the body, from end to end, corresponding in position with the internal lateral bands. Those, however, situated towards the posterior extremity of the body are most favourable for examination, owing to their increased number, size, and distinctness in this situation (Plate XXVIII. figs. 3 & 4). Extending through the chitinous portion of the integument they are about $\frac{1}{2000}''$ long, capillary in breadth, commencing internally opposite a conical projection of the true skin, and terminating at the external surface in a minute depression. That these are channels through the integument I have not the slightest doubt. I have detected similar pores in another freshwater species (*Tripyla glomerans*) having an unusually thick integument; in this also the pores were in the lateral regions of the body, though they did not exist in nearly so great abundance as in *Dorylaimus stagnalis*. Amongst the marine species I have recognized similar integumental channels most plainly in *Leptosomatum gracile*, *L. figuratum* (Plate XXVIII. fig. 33), and in *Phanoderma Cocksi* n the lateral cervical regions, though also less distinctly in the lateral region throughout the body. In addition they occur along the mid-dorsal and ventral lines of the *Leptosomata*. In *Oncholaimus vulgaris* they also exist in the mid-ventral and dorsal regions,

* Untersuch. über Nemat. 1863, p. 8.

as well as in the lateral, and I have seen them in the former situations only in members of the genus *Enoplus*.

EBERTH * seems to have recognized similar structures in a species of *Leptosomatum* (his *Phanoglene bacillata*), though he put a different interpretation upon what he saw, and called the structures "skin-glands" (Hautdrüse). It must be admitted that the recognition of their real nature is not so easy in the marine species as it is in *Dorylaimus stagnalis*. In this latter their nature scarcely admits of a doubt; but the homology of the structures to be seen in this animal with the almost similar structures which may be detected in many of the marine species, as well as in the *Trichosomata*, is also unquestionable. I have found these channels made much more apparent after the integument has been swollen somewhat, and rendered more transparent by immersion of the animals in strong glycerine for about twenty-four hours†. Although only yet detected in the larger species, I suspect these pores exist in a considerable proportion of the free Nematoids. There seems to be, however, evidence to show that none such are present in the representatives of the four genera *Tylenchus*, *Cephalobus*, *Aphelenchus*, and *Plectus*. Concerning the species of these genera I shall have to speak further on, and also of the probable use of the integumental channels to those species in which they exist.

In one only of the parasitic Nematoids have I seen a very close approximation to this arrangement of the integumental channels, and that was in *Heterakis acuminata* from the frog. In this animal similar integumental pores may be seen, apparently in single file, along the lateral aspects of the body (Plate XXII. fig. 12), about $\frac{1}{285}''$ apart. On the caudal extremity of the males these seem to be still more numerous and scattered over the surface generally, in addition to the well-marked ventral suckers met with in the same individuals (Plate XXII. fig. 13, *c*). But in the genera *Trichosoma* and *Trichocephalus* such pores are extremely numerous, and give rise, more particularly in the species of the latter genus, to an altogether exceptional appearance which has long been a puzzle to anatomists; although, on the other hand, in many species of the genus *Trichosoma* there is a much closer resemblance to what we meet with amongst the free Nematoids.

DUJARDIN, describing *Trichocephalus dispar*, speaks of the integument as "strié transversalement avec une bande longitudinale hérissée de petites papilles." WEDL and KÜCHENMEISTER ‡ give confusing and rather unintelligible statements concerning the same structure; but Dr. COBBOLD, in his recent work §, after alluding to these various opinions as to the nature of the peculiar widening band extending along one side of the body in different species of *Trichocephalus*, speaks in the following definite manner con-

* Untersuch. über Nemat. pp. 8 & 19, pl. 2, fig. 1.

† This is by far the best medium in which to mount the free Nematoids—at all events for species which are not less than $\frac{1}{10}''$ in length. At first they shrivel up, and the specimens appear to be ruined; but after from twenty-four to forty-eight hours the glycerine has passed into their interior, causing them to resume their natural form, and making them very transparent. So mounted they undergo little change.

‡ Manual of Parasites (Syd. Soc. Transl.), pp. 325, 326.

§ Entozoa: an Introduction to the Study of Helminthology, 1864, p. 71.

cerning this, as met with in *T. affinis*:—"According to my own observations this band is a genuine structure, and is made up of projecting, bluntly-pointed, polygonal epidermal cells, which in certain adjustments of the focus refract transmitted light so strongly that the band looks as if it consisted of a regularly arranged series of pigment spots (fig. 3, *a*); at other times the centre of each cell becomes clear (*a*), and the irregular polygonal character of each individual cell is rendered more apparent." Dr. EBERTH seems to have examined most carefully many species of the genera *Trichocephalus* and *Trichosoma*, and has also expressed very concise opinions concerning these bands of which we have been speaking. According to him *, these appearances are caused by solid staff-like prolongations into the substance of the skin, given off from and situated upon certain closely-packed, cylindrical, or elongated-polygonal cells,—the whole structure representing a variety of the dorsal median line as it exists in these Nematoids. He seems to think that the prolongations are developments from the cell-wall, and is decidedly of opinion that they are solid.

After the most careful examination of *Trichocephalus dispar*, *T. affinis*, and *Trichosoma longicolle*, I am unable to agree with any of these observers.

More than twelve months ago, before knowing anything of EBERTH'S observations (which do agree in some respects with my own), I was enabled to discover what I believe to be the real nature of these structures, during the examination of a specimen of *Trichocephalus dispar*, whose integument had been rendered more transparent by boiling the animal for two or three minutes in dilute acetic acid. Certainly there are no actual elevations of the integument into "papillæ" in the region of the band †, though the transverse markings decidedly cease at its borders (Plate XXVII. figs. 15 & 17); neither are there any "epidermal cells," as described by Dr. COBBOLD, and indeed their presence is quite irreconcileable with the chitinous nature of the epidermis in the Nematoids generally: both these appearances are, I believe, purely optical delusions, owing to errors of interpretation. I differ from EBERTH with respect to the description he gives of this band in one point only, though that is a most important one. What he considers as solid staff-shaped prolongations I believe to be integumental channels, essentially similar to those which I have previously described as so common in the free Nematoids. This would scarcely be imagined from an examination of the band throughout the greater part of its extent; but its posterior termination is by no means abrupt, and in that region its constituent elements are scattered widely apart and are quite isolated from one another before they entirely disappear on the thicker portion of the body. An examination of this region permits these integumental channels to be seen under different aspects (Plate XXVII. fig. 16), and enables their real nature to be more

* Untersuch. über Nemat. 1863, p. 46.

† Unless we so term, with DUJARDIN, certain larger rounded prominences of the integument often seen bounding the band in some portions of its length—"papilles plus grosses qui se gonflent par endosmose." These are altogether unimportant structures, due simply to a partial separation (such as we may often meet with in the Nematoids) of the most superficial lamella of the epidermis from that beneath it.

clearly perceived. When the mouth of the channel is looked down upon, and brought into focus at the surface of the integument (where it corresponds with a minute depression), it appears as a bright circular space about $\frac{1}{15000}''$ in diameter; and as the focus is lowered a dark roundish or polygonal halo is developed around it, giving rise to an appearance which led Dr. COBBOLD to speak of epidermal cells with clear central spaces. This dark border I believe to be due simply to an alteration in the diffraction of light by the bounding walls of the integumental channel, and the upper extremity of the columnar cells beneath coming into focus as the object-glass is lowered. In the *Trichocephali*, only one such band exists in the dorsal aspect of the anterior part of the body; but in the various species of the genus *Trichosoma* more commonly two exist, which may be either dorsal and ventral, or lateral *. In the members of this genus the pores are frequently not nearly so numerous, and in *Trichosoma longicolle* at least (the only specimen that I have examined), both these and the cellular bands beneath seem to approximate very closely to what we meet with in the free Nematoids (Plate XXVII. fig. 14); and in which also, as just stated, we see the same variation as regards the situation of the integumental channels.

Yet other openings through the integument remain to be spoken of, which, so far as I have observed, exist only in the parasitic species, and of these never in the *Trichocephali*, *Trichosomata*, or *Heterakis acuminata*. I allude to two lateral openings, of a much larger kind than those previously described, situated one on each side of some portion of the œsophageal region of the body, and two posterior latero-ventral openings, of the same character, between the anus and the posterior extremity of the animal †. These structures have been observed both by SCHNEIDER and EBERTH; by the former they have been described respectively as "cervical and caudal papillæ" ‡, and by the latter as openings of the water-vascular system §. In many of the Nematoids in which they are met with, these structures do present such an appearance as to lend support to Dr. SCHNEIDER'S view as to their nature, inasmuch as they are almost identical in their structure with the ventral papillæ of male *Ascarides*, consisting generally of a conical projection of the deep layer of integument into the inner part of the chitinous layer, where it is in connexion with a distinct channel through this substance opening in the centre of a surface-depression. But in *Ascaris lumbricoides*, the animal in which, quite independently, I first recognized these openings, the anterior channels through the integument are altogether so marked and well developed in proportion to the granular projection (Plate XXII. figs. 14 & 16), that from the first I looked upon the integu-

* EBERTH, Untersuch. über Nemat. Taf. vi. u. vii.

† Two similar lateral openings are spoken of by EBERTH in *Spiroptera uncinata* as existing near the middle of the body, posterior to the vagina. I have seen such median openings also in one species, but having made no note of it at the time, cannot be quite sure as to the animal in which they were seen—I think, however, it was in *Strongylus filaria*.

‡ Neue Beit. zur Anat. und Morph. der Nematoden, REICH. and DU BOIS-REYM. Archiv, 1863, p. 15.

§ Würtzb. Naturwiss. Zeitsch. 1860. Erst. Bd. Taf. ii. 3 *a*, u. Taf. iii. 13 *a*; Untersuch. über Nemat. Taf. viii. u. ix.

mental pore as the essential portion of the structure, and have never considered them to be tactile papillæ. This impression regarding their nature is rendered even more probable by what we see in *Prosthecosacter inflexus* (Plate XXVII. figs. 1 & 2). It seems, moreover, difficult to imagine what could be the use of papillæ in these situations, though it does appear to be a pretty constant rule amongst the Nematoids for the deep cellular layer of the integument to communicate with the exterior by means of channels through the chitinous envelope. No fine integumental pores, such as we have hitherto described, exist in the majority of the parasitic Nematoids, but so far as we have examined, both EBERTH, SCHNEIDER, and myself have found in these animals the larger cervical and caudal openings. May they not be looked upon as in a measure substitutes for one another? This opinion is also supported by the fact that the surface-depression into which they open is occasionally so marked as to discountenance the idea that they are to be looked upon as papillæ. The view entertained by EBERTH, that these pores are openings of the water-vascular system, I have no hesitation in believing to be erroneous. SCHNEIDER also is quite opposed to this interpretation of their function. After repeated examinations I have quite satisfied myself that, though situated externally to the lateral bands, these integumental channels have no communication with the longitudinal vessels often contained within them. Such pores exist on *each* side of the cervical region of *Ascaris osculata*, though vessels are present only on the left side (Plate XXVI. fig. 9); and again, in *Cucullanus heterochrous*, the caudal pores are distinctly posterior to the cæcal terminations of the lateral vessels* (Plate XXVII. fig. 12, *a* & *b*).

In *Ascaris lumbricoides*, in addition to the papillæ already described as existing on its cephalic lobes, I have detected certain integumental channels of two kinds; the first being two in number, and situated one on each side on the latero-ventral lobe, near its upper border and anterior to the level of the larger central papilla (Plate XXII. figs. 14 & 19, *c*). At these points the cellulo-granular layer is formed into a conical projection which reaches the surface at a slight depression in the chitinous envelope (Plate XXII. fig. 18, *c*, *d*), and communicates with the exterior by means of a small circular aperture. The other channels (two on the anterior border of each lobe) are very minute, and are mere capillary passages through the thick chitine in this situation (Plate XXII. figs. 18 & 19, *e*, *e*), with no apparent projection of the cellular layer beneath. In all probability both these kinds of channels are to be met with in the cephalic lobes of other *Ascarides*.

* In a species of *Dispharagus*, from the gizzard of *Colymbus septentrionalis*, I found the caudal openings, though I could not recognize the cervical. I did find, however, in this region, on each side of the body, a projection of the chitinous integument (Plate XXII. fig. 1). KÜCHENMEISTER represents lateral cervical projections of this kind also in *Anchylostomum duodenale*, and I have likewise seen them in a red-coloured *Strongylus* from the stomach of a hare. I was, however, unable to recognize perforations through these structures. In the females of the last-mentioned animal also the two caudal pores seemed to be replaced by a large number of integumental channels distributed over the whole circumference of this region of the body; though in the males two well-marked lateral pores were visible just above the level of the bursal expansions. They are very long, on account of the thickness of the integument in this region.

In many of the free Nematoids peculiar circular markings are met with close behind the head, on either side of the body; in others, compressed spiral instead of circular markings exist; whilst in some, circular depressions or convex projections are substituted for these markings, in the same region*. I have examined these structures most carefully with one of POWELL and LEALAND'S $\frac{1}{25}''$ object-glasses, but could never detect any aperture or internal vessel in communication with them; they seemed to be simple markings, elevations, or depressions of the integument unconnected with any other structure. In the members of the genus *Plectus*, however, somewhat similar markings exist, which are undoubtedly connected either by a minute pore or by a thinning of the integument in this situation, with the anterior extremity of a lateral vessel (Plate XXVIII. fig. 14).

It seems now to be an undoubted fact that, during the period of growth of the Nematoids, both free and parasitic, a periodical shedding and renewal of the chitinous portion of their integument takes place. This was I believe first recorded by EHRENBERG as occurring amongst the free Nematoids. Amongst these I also have seen animals belonging to several genera with the old integument separated from, though still more or less investing the animal, as well as at an earlier stage, when the demarcation between the old and the new chitine is indicated by a sharply defined undulating line. In some species of the genera *Oncholaimus* and *Cyatholaimus* it seems to separate in distinct shred-like pieces instead of being thrown off entire. In the genus *Enoplus* the three teeth are shed and renewed with the integument. Amongst the parasitic species I have seen a specimen of the so-called *Filaria piscium* completely shed this same chitinous portion of its integument, which phenomenon has also been described by DUJARDIN as occurring in *Hystrichis tricolor*, and by DIESING in *Ascaris depressa*.

MUSCULAR SYSTEM.

Almost all Nematoids seem to possess four great longitudinal muscles running along the whole length of the body, and separated from one another only by the lateral and median lines. In the species, however, in which the median lines do not exist, there is often no distinct separation between the two dorsal or the two ventral muscles, and accordingly it has been asserted by some that two great longitudinal muscles only exist, an upper and a lower. With regard to the presence or absence and distribution of transverse fibres, much difference of opinion has existed. CLOQUET† has described transverse muscular fibres external to the longitudinal in *Ascaris lumbricoides*, and OWEN‡ the same in *Strongylus gigas*; both speak of the close adhesion of these to the chitinous integument. DE BLAINVILLE§ speaks of transverse fibres internal to the longitudinal, and VON SIEBOLD|| doing the same, correctly points out that these do not form complete rings, but are as it were separated into four segments by the longitudinal lines.

* See figures, *loc. cit.*

† Sur les Vers Intestinaux, 1824, p. 17.

‡ Cyclop. of Anat. and Phys., Art. *Entozoa*, p. 129.

§ Dict. des Sc. Nat. tom. iii. App. p. 40.

|| Manuel d'Anat. Comp. note, p. 119.

These transverse fibres, such as are alluded to by SIEBOLD, have been looked upon as vessels by BOJANUS*, CLOQUET, DIESING†, WALTER‡ and others, whilst they were suggested by MEISSNER§ to be branches of the peripheral nerve-trunks, similar to what he erroneously considered to be the nature of homologous processes in the *Gordiaceæ*. SCHNEIDER and EBERTH, as well as myself, are quite agreed as to the nature of the transverse fibres described by SIEBOLD, and in speaking of the histology of the muscles, I shall fully describe their origin and distribution.

In addition to these principal muscles extending through the body generally, there are other smaller local fasciculi, some common to both sexes, for the opening and closure of the anal cleft, whilst others are peculiar to the male. They are, besides bundles for the protrusion and retraction of the spiculi, a series of fibres—always well marked in the genus *Ascaris*—extending on each side, for some distance above the ano-genital opening, from the lateral bands to the mid-ventral region and median line (Plate XXIII. figs. 3 & 4). These are most developed, and constitute gradually thicker bundles posteriorly. In *A. osculata* they attain an enormous development, and separate the longitudinal muscles into three nearly equal bands ||, their extremities completely obliterating and occupying the place of the mid-ventral and lateral lines (Plate XXVI. fig. 12). In *A. lumbricoides* these peculiar fibres may be met with in the males for about a distance of $1\frac{1}{2}''$ from the posterior extremity of the body, so that the extent of their distribution corresponds exactly with that of the ventral papillæ before described; which leads me to believe them to be destined to flatten the ventral region of the male, and so enable the papillæ, whether suctorial or simply tactile, to be brought into contact with the body of the female when the posterior extremity of the body of the male is coiled round it *in actu coitûs*.

The bands of longitudinal muscles vary much in thickness in different species; they are much more developed, for instance, in *A. megalocephala* than in *A. lumbricoides*, and in the males, of all species of *Ascaris* at least, form much thicker bands than in the females. In the male the cavity of the body frequently becomes much diminished, owing to the encroachment upon its area by the four thick convex longitudinal masses of muscle.

We are indebted to Dr. SCHNEIDER¶ for a most accurate account of the histological structure of the muscles in the Nematoids, and though his views have been questioned

* Isis, 1821, p. 187. pl. iii. figs. 51 & 54.

† Annal. d. Wiener Mus. ii. part 2, pl. xvi. fig. 1, et pl. xviii. fig. 2.

‡ VIRCHOW's Archiv, 1862, Bd. xxiv. p. 166. Taf. iii.

§ MÜLLER's Archiv, 1856.

|| These three bands are produced in this manner:—in the male Nematoids, towards the posterior extremity the lateral lines deviate from their median position and run closer to the dorsal surface. Here also the dorsal median line is often wanting, and the two diminished dorsal muscles blend into one band, about equal in size to each of the ventral longitudinal muscles, and so produce an arrangement similar to what MEISSNER has described as generally existing in the genus *Mermis*.

¶ MÜLLER's Archiv, 1860, S. 224.

by WALTER, the results of my own researches are mostly in accordance with them, and EBERTH* has also testified to their correctness.

Speaking generally, the longitudinal muscles may be said to be composed of a series of small muscle-cells varying in form between an elongated spindle and a rhomboidal shape, each of which is composed of one portion (cortical) altered in structure by its conversion into fibrillæ, and another less altered portion varying in its proportional extent, containing in the midst of the granular medullary substance of which it is composed one or more nucleated cells, and often sending off a transverse prolongation to, or in the direction of, one of the median lines. In their most divergent types two well-marked differences exist in the nature of these muscle-cells in different species of Nematoids, though intermediate states may be seen, which clearly point out these varieties to be nothing more than modifications of one common plan. This distinction was first noted by Dr. SCHNEIDER, and he proposes to divide the Nematoids into *Platymyariæ* and *Colomyariæ*, according as they agree most with one or other of these types of muscle-formation. As illustrations of the first type, we have the *Spiropteræ*, *Strongyli*, and *Oxyurides*, whilst the second is seen to perfection in the members of the genus *Ascaris*.

Beginning with the simpler forms, the *Platymyariæ*, we may take the *Spiroptera obtusa* as a good illustration. In this animal the muscle-cells are flat, and of a somewhat elongated rhomboidal form†, accurately dovetailing in with one another so as to form four continuous layers separated from one another by the longitudinal lines‡. On the surface they have a granular aspect, and present a nucleated cell generally near the centre imbedded in this granular material. By the aid of thin transverse sections of the animal we obtain a much clearer insight as to the precise structure of each muscle-cell§, and are enabled at once to see that each is composed of an external solid contractile portion, and an internal granular matter bounded by a loosely fibrous envelope (Plate XXVI. fig. 21). We shall speak more fully of these various parts after having described their modifications met with in animals of the other type.

The structure of the muscles in the *Colomyariæ* may be well studied in any of the *Ascarides*, and in none better than in *A. lumbricoides* and *A. megalocephala*, where the type attains its greatest complexity. Whilst in *Spiroptera obtusa* the breadth of each muscle-cell at its widest part considerably exceeded its depth or thickness, in these animals, on the contrary, the depth considerably exceeds the breadth, and they exist as triangular cells with a more or less elongated base (Plate XXIII. figs. 8 & 9), by which they are attached to the deep integumental layer, whilst their other sides and apices, from

* Untersuch. über Nemat. 1863, p. 64.

† Untersuch. über Nemat. Taf. ix. 3.

‡ SCHNEIDER has pointed out what he considers to be the general arrangement of these muscle-cells in the *Platymyariæ*, after what he has more especially observed in *Oxyuris curvula*. (REICH. and DU BOIS-REYM. Archiv, 1863.)

§ There is a great apparent difference in the size and breadth of contiguous cells, simply owing to the section having passed through these in most cases at varying distances from their central or broadest part—a section which passes through nearly the centre of one cell may intersect the narrow extremity only of the next.

which certain processes are given off, project into the general cavity of the body*. These several cells are in close apposition with one another, and are accurately dovetailed together, as can be well seen in transverse sections (Plate XXV. fig. 13); these also show that the attached portion is the narrowest part, the free edges being thicker and rounded. The section of each bundle, according to its size, exhibits more or less granular matter in its centre, which in the smaller and medium-sized bundles is completely enclosed by the striped fibrous portion of the cell, whilst in the larger the central cavity and contained granular matter become more distinct and communicate with a more or less pronounced, bladder-shaped, fibrous prolongation (Plate XXIII. figs. 5 & 8). Now if we imagine the sides of one of the flat cells described in *Spiroptera obtusa* to grow up, approximate to one another, and close in completely over the granular matter except at its central portion, we should have a formation similar to that just described as actually existing in the *Ascarides*. A section of either extremity of the cell would also show granular matter completely enclosed by the fibrous contractile portion, whilst one through its centre would reveal a continuity between its central cavity and that of a small fibrous prolongation from it. The two forms are thus seen to be only modifications of a common plan, between which a complete series of transition states can be recognized in the structure of the muscle cell as met with in other different species of Nematoids (Plate XXVI. fig. 3). When one of these triangular cells of the *Colomyariæ* is seen lying on its side, it seems to be made up of a number of fine fibres, having a longitudinal direction and a parallel closely packed arrangement, with no trace, however, of transverse striation (Plate XXIII. figs. 8 & 9). But in transverse sections it is seen that what appear to be simple fibres when viewed from the exterior, are in reality a series of band-like fibres, each of which extends from the exterior to the central granular matter of the cell (Plate XXV. fig. 13). No appearance can be detected leading one to believe that these apparent bands are composed really of transverse rows of narrower fibres. This structure of the contractile portion of the body of the muscle-cell is essentially similar in both *Colomyariæ* and *Platymyariæ*.

Much difference exists, both amongst the two groups and in the several members of each, as to the degree of complexity of the remaining processes of the muscle-cell. They are usually more simple in the *Platymyariæ*. But in Nematoids generally we may, I think, recognize two distinct varieties of these processes, the one being more or less developed representatives of the bladder-like growths so distinct in *Ascaris lumbricoides*, and the other answering to the transverse processes (Fortsätzen) extending from the muscle-cells to the median lines—also well developed in the same animal (Plate XXIII. fig. 2). The bladder-like processes are frequently but very little developed, and may be seen in their simplest condition in *Spiroptera obtusa*, where they are merely the internal bounding portions of the muscle-cell, composed of fibrous walls (Plate XXVI. fig. 21) enclosing the granular matter and contained nucleated cell, which rest on its

* After maceration for two or three weeks in dilute nitric acid the muscles are readily resolved into their component cells.

proper contractile portion. In *A. lumbricoides*, on the contrary, they are more developed than I have met with in any other Nematoid. In this animal they correspond to the "appendices nourriciers" of CLOQUET. The granular matter of the muscle-cell is here enclosed on all sides by the contractile portion, except at one point corresponding to its apex, and in this situation there is a bladder-shaped development communicating with the medullary portion of the cell only by a more or less narrow connecting isthmus (Plate XXIII. figs. 5, *n*, & 8). There seems to be a direct continuity between the body of the cell and the simple fibres composing the parietes of these bladder-like portions. In *Ascaris lumbricoides* these prolongations exhibit also a fibrous network in their interior, amongst the meshes of which are contained numerous bright highly refracting granules (Plate XXII. fig. 22). In *Dracunculus medinensis* these internal fibres are still more developed into smaller and stronger loculi, in the midst of which is situated the nucleated cell (Plate XXV. fig. 15). From the surface of the bladder in *A. lumbricoides* numerous delicate fibres are given off, which serve to connect this with similar neighbouring processes, and with the axial intestinal canal in the first part of its extent.

The other kind of process arising from the muscle-cells consists of narrow band-like prolongations, proceeding in a direction at right angles from the muscle-cell to the adjoining dorsal and ventral median lines, where these are present. They necessarily vary in length according to the distance between the longitudinal line and the muscle-cells from which they emerge. They are the "transverse muscles" of DE BLAINVILLE and Von SIEBOLD, and the vessels or nerves of other writers. In *Ascaris lumbricoides* their direction and arrangement can be well seen in transverse sections. In this animal some of the muscle-cells appear to give rise to transverse processes only, whilst in others a bladder-like prolongation may be seen as well. These transverse prolongations are composed of fibres and intermixed granules (Plate XXV. fig. 13), and are apparently directly continuous with the body of the muscle-cells, as originally stated by SCHNEIDER, though WALTER* has since denied this. EBERTH'S† views are in accordance with those of SCHNEIDER and myself. The nucleated cell of the medullary substance is situated close to the origin of the transverse process, where this exists. In different Nematoids a great variation is met with in the abundance of the transverse processes, and generally they may be best studied, on account of their simplicity, in the *Platymyariæ*. EBERTH has well represented them as they exist in *Heterakis vesicularis*‡, whilst in *Spiroptera obtusa* they are less developed still, leading on to what obtains in other Nematoids where they are absent altogether. This is the case according to EBERTH in *Ox. ambigua* and *A. oxyura*, and according to SCHNEIDER in *Pelodytes strongyloides* and some of its allies. I have never met with them either in *Dracunculus medinensis*, or in any of the free Nematoids.

As before stated, in many Nematoids no median dorsal and ventral lines exist, though

* VIRCH. Archives, 1860. † Untersuch. über Nemat. 1863, p. 67.

‡ Würzb. Naturwiss. Zeitsch. 1860, Erst. Bd. Taf. iv. 22.

the transverse processes are by no means necessarily absent in these same animals, as I have well seen in *A. osculata*. In this species there is a distinct slightly sinuous interspace between the two great longitudinal muscles in the mid dorsal and ventral regions in the usual situation of the longitudinal lines, and the transverse muscular prolongations are seen tending towards it, over which some of those from opposite sides unite with one another instead of having a common attachment to the ordinary longitudinal projections of the skin in this situation, whilst others seem to bend down to attach themselves to the skin exposed in this muscular interspace.

In *Prosthecosacter inflexus* the muscle-cells, when seen in transverse section, are found to be extremely narrow as compared with their depth, and present the appearance of closely packed bundles with the usual transverse markings (Plate XXVII. fig. 5). But whether these animals are to be looked upon as *Platymyariæ* or *Colomyariæ* seems altogether doubtful—at all events I have never been able to recognize any granular matter between pairs of bundles, as would be the case if they belonged to the latter type. A small amount of granular matter is seen at the surface, and a number of fine fleecy processes having an irregular disposition *, though I can say nothing more definite concerning them.

If we now inquire as to the use of these transverse muscular prolongations so prevalent in the Nematoids, I think we shall have no difficulty in answering the question. Supposing the four sets of fibres to contract at the same time, they must necessarily tend to diminish the calibre of the cavity of the body, and so exert a compressing force upon the intestinal canal, tending to urge its contents in a definite direction according to the order of their contraction. And seeing that no muscular fibres have been detected in the intestinal canal itself, except at its two extremities, this seems to be the function which they are destined to perform.

Many anatomists have spoken of the existence of circular muscular fibres external to the longitudinal. I have not only utterly failed to recognize the existence of such, but am also quite at a loss to know what possible use they could subserve even were they present—situated as they would be on the one side within a firm chitinous cylinder, practically incapable of being contracted, and on the other external to the very strong muscular envelope formed by the great longitudinal bands.

Dr. Schneider believes the muscles of the *Trichocephali* do not conform in the type of their formation either to that of the *Colomyariæ* or the *Platymyariæ* †, though as regards the structure actually existing in *Trichocephalus dispar*, his views are at variance with those of Eberth. The latter believes that the muscles are lined internally with a layer of nucleated cells much resembling pavement epithelium, and seems disposed to doubt the organic continuity of these cells with the subjacent muscle tissue ‡. Schneider, on the contrary, speaks of the muscles being covered by a homogeneous layer

* Other fleecy processes having much the same appearance extend across the body, from lateral line to lateral line, diverging in their course to encircle the alimentary canal, and so suspend it in the axis of the cavity of the body (Plate XXVII. fig. 4).

† Reich. and Du Bois-Reym. Archiv, 1863, S. 20.

‡ Untersuch. über Nemat. 1863, S. 49.

of fine granular substance, having numerous interspersed clear spherical spaces or "vacuoles," at the same time believing this substance to constitute an actual portion of the muscle-cells, and to be in reality but another form of the "Marksubstanz." I am inclined to think that SCHNEIDER's description is the more correct from what I have seen in some of the free Netamoids, and more particularly so, as even EBERTH, in the same place, speaks of the resemblance of the muscles of these latter to those of the *Trichocephali*. Thus in *Symplocostoma longicollis* I have seen a similar finely granular material lying on the surface of the muscles containing in its substance what appear to be bright spherical spaces (Plate XXVIII. fig. 132), since they have no defined boundary wall*. This substance also exists in the form of a multitude of long-tailed processes extending into the cavity of the body, each of which has a similar bright space in its dilated free extremity. Whether, however, this is an independent layer of glandular substance merely lying on the muscles and differing from the ordinary "Marksubstanz," or medullary portion of the muscle-cells, I am unable to say†. I think it possibly may be so, since I have recognized the rudiments of a somewhat similar granular layer (Plate XXIII. figs. 8 & 9, *e*) on the surface of the triangular muscle-cells of *A. lumbricoides*‡. And if this is really the case, we have only to suppose the development of this substance to be extreme whilst that of the bladder portion of the cell is in abeyance, to reconcile the type of muscle-formation in the *Trichocephali*, and certain of the free species, with that of other Nematoids, since EBERTH'S observations agree with my own as to the presence of fibrous processes (Fortsätzen) in the former animals; whilst with regard to the free Nematoids, the difficulties of the investigation are such that we can only say that no such processes have yet been detected in them. The animals are too small to enable satisfactory transverse sections of the requisite tenuity to be made; neither can their bodies be slit with more ease in a longitudinal direction.

NERVOUS SYSTEM.

Most various and discordant have been the statements made from time to time concerning the nervous system of the Nematoids; some mistaking for it portions of the integumentary, muscular, or even alimentary organs, whilst others have been unable to recognize any traces of such a system in these animals.

CUVIER and SERRES seemed to be of opinion that the Nematoids possessed two lateral nerves, in all probability mistaking the lateral integumental bands for these; whilst

* I should, however, be inclined to look upon them as jelly-like masses of a transparent albuminous material rather than actual vacuoles.

† The structure which in the paper on the Guineaworm (*loc. cit.*) I described and figured as a layer of tessellated nucleated cells lying on the muscles in that region of the body compressed by the development of the genital tube, I now believe to be actual parts of the muscle-cells similar to those figured in the present memoir (Plate XXV. fig. 15), merely altered in appearance by the pressure to which they have been subjected, and actually *torn* from the surface of the muscles by the scraping process necessary for their removal.

‡ I had actually sketched such a structure before I was aware of these doubts concerning the *Trichocephali* and free Nematoids.

the smaller dorsal and ventral cords of a similar nature in *A. lumbricoides* have been described as nerves by OTTO* and CLOQUET†. The former also described a ventral cord in *Strongylus gigas*, giving off a few transverse branches in its course and ending at either extremity of the body in a terminal swelling. OWEN‡ describes a somewhat similar structure in this animal, but adds that it commences and ends with slender nervous rings around the anterior portion of the œsophagus and the anus respectively. From the description given by him of this ventral cord, and the disposition of its branches, one is led strongly to believe that it in reality corresponds to the ventral median line with its attached transverse muscular processes; although SIEBOLD § distinctly states his belief that the ventral cord seen in *Strongylus gigas* is of a different nature from that met with in *A. lumbricoides* and other Nematoids, and adds as a description of a structure then before him, "Dans son trajet il envoie une multitude innombrable de filets latéraux, qui par leur structure intime, *différent essentiellement des faisceaux musculaires* transversaux." Professor OWEN affirms, however, that this ventral cord passes "to the left side of the vulva, and does not divide to give passage to the termination of the vagina, as CLOQUET describes the corresponding ventral cord to do in *Ascaris lumbricoides*." He agrees with OTTO in the statement that only a ventral cord exists in this animal, though BLANCHARD suggests that this may have been a mistake, owing to the destruction of the dorsal cord by the section of the body of the animal in the mid-dorsal region. BLANCHARD ‖ also considers the dorsal and ventral lines to be the extremely developed peripheral portions of the nervous system in the Nematoids. He says that in all the representatives of the order he has found "une disposition tout-à-fait semblable dans l'appareil de la sensibilité," which he describes in these words:—"le corps placé dans la position où les deux nerfs principaux¶ se trouvent être latéraux, on observe de chaque côté de l'œsophage deux très-petites masses médullaires placées exactement sur le même plan, et unie à celles du côté opposé par une double commissure extrêmement grêle, l'une passant alors au-dessus de l'œsophage et l'autre au-dessous." In the *Ascarides* and *Filariæ* these ganglia are, he says, double on each side, but in the *Sclerostomata* they become fused into one. Nothing answering to this description has been met with by other observers, and the same must be said of the double nervous cord figured and described by Professor GRANT** as traversing the ventral region of the body in *Ascaris lumbricoides*.

MEISSNER†† described the transverse muscular processes in the *Gordiaceæ* as branches of a peripheral nervous system, and put the same interpretation upon the homologous prolongations in the *Nematoidea*; and at one time HUXLEY‡‡ seemed inclined to assent to the same view of the nature of these transverse muscles in the Nematoids. WALTER§§ formerly described a most elaborate system of nervous ganglia and cells with peri-

* Magaz. d. Gesell. Nat. Fr. Berlin, vii. 1814.

† Sur les Vers Intestinaux, 1824, p. 23.

‡ Cyclop. of Anat. and Phys. vol. ii. p. 130.

§ Man. d'Anat. Comp. (Trad. Franç.) p. 126, note.

‖ Ann. des Sc. Naturelles, 3me sér. 1847, p. 124.

¶ Dorsal and ventral median lines.

** Outlines of Comp. Anat. p. 186, fig. 82 A.

†† MÜLLER's Archiv.

‡‡ Lecture in Med. Times, 1856, vol. ii. p. 384.

§§ Zeitschr. fur Wissensch. Zoolog. 1857.

pheral filaments in *Oxyuris ornata*, though he has since very honestly confessed the errors into which he had fallen on that occasion, and now admits to a great extent that no such system is to be met with in the animal in question.

In the paper "On the Structure and Nature of the Dracunculus" *, I myself described as belonging to the nervous system two very peculiar ganglionated cords which traverse the centre of each intermuscular lateral space. I have since repeatedly examined these structures, and although I now entertain considerable doubts about their belonging to the nervous system, I have no modifications to make in the description I then gave of their actual structure. They remain a perfect puzzle to me, and I can offer no suggestions as to their real nature.

In his recent work on 'Entozoa,' Dr. COBBOLD expresses his belief that what is now looked upon by most anatomists as an axial vessel or excretory canal in the lateral bands, should rather be relegated to the nervous system. Speaking of these structures in *Ascaris lumbricoides*, he says, "I find the lateral lines characterized by a band of large granular cells, in the centre of which lies a well-marked double-bordered canal containing fine granular matter. I cannot call the inner tube a true nervous cord, but at the same time I am willing to believe that it represents a rudimentary condition of a true nerve-system." This view is entirely unsupported by evidence, and is, moreover, directly opposed to the existing state of knowledge.

At last, after this maze of conflicting statements, we come to something more definite, and likely to bear the test of scrutiny, in the recent accurate investigations of SCHNEIDER † upon the nervous system of the Nematoids; the clue to which was given by the observation of LIEBERKUHN, WEDL, and himself at an earlier period, of a pale band surrounding the anterior part of the œsophagus. Bearing this in mind, and following it up at a later period by dissections conducted in the most careful manner, he succeeded in detecting in *Ascaris megalocephala* and other Nematoids what is undoubtedly the most essential portion of their nervous system.

In EBERTH'S ‡ most interesting memoir, published about the same time, upon the anatomy of both free and parasitic Nematoids, after mentioning diverse structures which might possibly be taken to represent parts of a nervous system, he evidently remains of the opinion that, so far as he has seen, there is no structure in the Nematoids that he could with confidence look upon as the representative of such a system. He appears, however, never to have carefully examined either *A. lumbricoides* or *A. megalocephala*, which are the most favourable species at present known for the detection of this structure. Up to within quite a recent period the views that I had arrived at (quite independently) accorded almost precisely with those held by EBERTH. I was far from disposed absolutely to deny the existence of a nervous system in the Nematoids, but after a pretty careful examination of many species I had utterly failed to recognize anything which I could look upon as belonging to a nervous system, and must confess felt very sceptical

* Trans. of Linn. Soc. vol. xxiv. p. 111.

† REICH. and DU BOIS-REYM. Archiv, 1863, S. 1.

‡ Untersuch. über Nemat. 1863.

upon the subject. Latterly, however, I have been able to confirm the accuracy of SCHNEIDER'S statements in every particular, and have no longer the shadow of a doubt that the similar structures which we have both recognized in these and other Nematoids do constitute the most important portions of a nervous system.

The difficulties besetting the proper recognition of this system are, however, extreme, owing to the intimate and confusing manner in which it is mixed up with a blending of processes from the lateral and median lines, and a multitude of offshoots from the neighbouring muscles.

SCHNEIDER has detailed very fully the different parts of the nervous system as they exist in *A. megalocephala*, and as I have myself recognized them in individuals of the same species; so that I shall describe as briefly as possible what I have made out in the nearly allied species *A. lumbricoides*, and one or two other members of the same genus.

The best method for preparing the nervous system for examination in either of these animals is that recommended by SCHNEIDER, and is as follows:—Select if possible a rather young specimen, on account of the greater transparency of its tissues, cut off a portion about $\frac{1}{2}''$ in length from the anterior part of its body, and having previously settled which is the dorsal median line*, insert the point of a fine scissors within the cut extremity of the œsophagus, and then slit open this, together with the body wall, in the mid-dorsal region. The head lobes may be either cut off or left The posterior corners of the opened body wall should now be pinned out whilst the œsophagus is being carefully stripped off. The specimen should then be boiled in dilute acetic acid for about two minutes, after which the thick cuticle may generally be stripped off, and finally the preparation should be mounted in glycerine to make it still further transparent. When saturated in this fluid the preparation will bear considerable pressure without injury, and so often enable ganglion-cells and their issuing fibres to be better detected.

In *A. lumbricoides* the nervous ring (Plate XXIV.) which constitutes the most marked portion of this system is situated about $\frac{1}{20}''$ from the anterior extremity, and is about $\frac{1}{333}''$ in breadth. It merely surrounds the commencement of the œsophagus, but is not closely adherent to it, though it is almost inseparably connected with the parietes of the body. It seems to embrace the œsophagus somewhat obliquely, the dorsal portion being nearest to the anterior extremity. The method of its connexion with the body wall may be best seen in transverse sections (Plate XXVI. figs. 1 & 11), when a fibrous ring is recognized with more or less nucleated ganglion-cells interspersed, divided into four equal portions by its contact and blending with developments from the lateral and median lines. Also it is intimately connected with the four great longitudinal muscles by means of fibres passing to and blending with it in the intervals between its other attachments. These muscular prolongations passing to the nervous ring may be considered as the most anterior representatives of those processes, which throughout most of the body posterior to this situation have a transverse direction, and are attached to the

* This may always be known by its having a single head lobe opposite its termination, instead of itself terminating between two, as is the case with the ventral line.

median lines. No such processes exist anterior to the nervous ring, and those proceeding to it, according to SCHNEIDER, together constitute a strong sheath in which are inclosed the real nerve-fibres. According to him, what is actually seen when the band crossing the anterior part of the preparation, made in the manner stated, is examined, is this fibrous sheath, which effectually conceals the real nerve-elements within it. I quite agree with SCHNEIDER in this view; for when the flat surface of the band is examined in this manner, no ganglion-cells or unmistakeable nerve-fibres can be detected in it, though the former elements may be easily recognized in well-made transverse sections, and the real nerve-fibres, according to SCHNEIDER, may be isolated by dissecting the ring after it has been boiled in dilute nitric acid.

In connexion with the ring, posteriorly, between it and the arch of the water-vascular system, are many most distinct ganglion-cells with issuing fibres, which are by no means easy of detection, since they are imbedded either in the lateral bands or amongst a web of most delicate fibres and interspersed granules, partly derived from the same lateral bands, and partly from the subjacent muscles. This is the case also with the nerves and cells anterior to the œsophageal ring. Some of the hindermost cells are, doubtless, obscured by the vascular arch, though I have never been able to ascertain that any existed posterior to this. The ganglion-cells behind the ring are arranged into four groups; two larger (*d*, *d*) occupying the substance of the lateral bands, and two smaller (*c*, *c*) diverging from a ganglionic mass in the mid-ventral region in connexion with the œsophageal ring. These ventral ganglion-cells appear to me to send a few fibres in a curved direction towards the cells in the lateral tracts, though the majority pass forwards to the œsophageal ring and median ganglion. It is from the cells in the lateral tracts that I have principally distinguished the issuing fibres; they may be distinctly seen as broad bands* directly continuous with the body of the cell, which contains a bright nucleus as well as a small quantity of fine granular matter. To ascertain the relative proportions, I measured these various parts in the cell marked *r*, and found them to be as follows:—diameter of cell $\frac{1}{588}''$, of nucleus $\frac{1}{3333}''$, and of fibre at slight distance from cell $\frac{1}{3333}''$.

In front of the œsophageal ring I could not find so many ganglion-cells existing in *Ascaris lumbricoides* as seem to be present in *A. megalocephala*, although in both species they are more abundant behind than in front of the ring. The most striking portions of the nervous system anterior to the ring are six great muscular bundles, which proceed forward to the mouth and cephalic lobes. The two bundles containing the largest number of fibres are contained in the substance of the lateral bands (*g*, *g*), *nervi laterales* of SCHNEIDER; whilst those which present the largest and most well-marked fibres are two bundles (*f*, *f*), which have been named by the same anatomist *nervi submediani*, situated on the ventral surface, on either side of the median line and about midway between it and the lateral bands; these have a serpentine course, and appear to go to the contiguous portions of the two under cephalic lobes. They seem to arise each by two

* According to SCHNEIDER, in transverse section they present a flattened oval appearance.

principal roots, though in what precise manner could not be detected, owing to these parts being obscured by the dense fibrous meshwork which extends for some distance in front of the ring, as well as over much of the space between this and the head. The fibres composing this network are in part, undoubtedly, connecting nerve-fibres, though the greater portion of the tissue seems to be composed of mere protecting fibres, probably derived from the muscles. Near the origin of these ventral *nervi submediani*, on either side, between them and the lateral tracts, are two small but distinct bipolar ganglion-cells (*k*, *k*), one fibre of which seems to come from the œsophageal ring, whilst the other connects the cell with one of the nerves in question. The dorsal *nervi submediani* (*i*, *i*) seemed to me principally derived from the ganglion-cells in the lateral tract posterior to the œsophageal ring, and appeared to curve gently upwards to supply the upper cephalic lobe. This lobe seemed also to derive fibres from two large nucleated ganglion-cells*, one of which is situated just external to each lateral tract (*h*, *h*), and also a small bundle of fibres from the *nervi laterales*. Although nerve-fibres have been detected only in the anterior part of the body of *A. lumbricoides* and other Nematoids, I have not the slightest doubt that peripheral branches do exist throughout the body generally; and from what I have seen of the course of one large fibre proceeding backwards from one of the lateral ganglion-cells, I suspect that they generally pass beneath the muscles to gain the deep cellular layer of the integument, in which they are principally distributed, and from which they can so easily give off filaments to the muscles or to tactile papillæ. I distinctly saw a fibre (marked *e*) leaving the substance of the lateral cord and passing beneath the muscular bundle lying outside it. Dr. SCHNEIDER seems inclined to think that some large nerve-fibres may pass posteriorly in the substance of the dorsal and ventral median lines, though he has never absolutely traced nerve-fibres passing from the central ring into these bodies. He rests his opinion upon the fact that in fine transverse sections which he has made of the median lines, he has found them perforated lengthwise by cavities having an elliptical or oval cross section; which tubes or cavities, he states, are invariably filled with a transparent, homogeneous substance of a reddish or yellowish tint. He says that from six to eight such bodies can be detected in the ventral median line of *A. megalocephala*, but only from four to six in the dorsal. These are considered to be transverse sections of nerve-fibres; but the fact that they have a distinctly larger diameter than the principal nerve-fibres issuing from the ganglion-cells seems to me strongly opposed to this view. I have myself been unable to recognize such structures in the median lines, so must refer for further details concerning them to Dr. SCHNEIDER'S important memoir.

The nervous system of *Oxyuris curvula* has also been carefully examined by SCHNEIDER, and in this animal he has found the œsophageal band most distinct, as well as the anterior fibres, though very few ganglion-cells could be detected. He has with difficulty, moreover, detected the most important parts of this nervous system in *Strongylus*

* These large cells have rather a remarkable appearance from their isolated position, but still the aspect of their nucleus and cell-contents corresponds most closely with that of other ganglion-cells.

armatus. I have also detected the œsophageal band and ganglion-cells in *Ascaris marginata, A. osculata, A. spiculigera, A. mystax*, and *Dracunculus medinensis*, and have seen, from the exterior only, what seemed undoubtedly the œsophageal band in *Strongylus filaria* and *Cucullanus heterochrous.*

LEUCKART has described a pale nervous band containing ganglion-cells surrounding the œsophagus, close behind the mouth, in *Oxyuris vermicularis*, and has also described * what he considers to be a nervous ring, occupying a similar situation, in *Trichocephalus hominis* and *Trichina spiralis.* EBERTH † has likewise seen a structure of the same kind in several *Trichocephali* and *Trichosomata*, though he seems very unwilling to look upon it as constituting part of a nervous system.

As to the peculiar, bright, homogeneous-looking ring surrounding the œsophagus in some parasitic Nematoids, such as EBERTH has figured ‡ in *Spiroptera megastoma* and *Sclerostomum dentatum*, there can, I think, be little doubt that this is homologous with the similar body surrounding the œsophagus of so many of the larger marine Nematoids, and concerning which both EBERTH and myself have already expressed our opinions that it does not belong in any way to the nervous system. It differs altogether from the nervous œsophageal band now distinctly recognized in so many Nematoids, not only by its position, which is often far removed from the mouth, but also by its structure and disposition. No fibres can be recognized in its tissue, it is considerably larger and thicker in size, and, in addition, seems to be connected more intimately with the œsophagus itself than with the parietes of the body.

Notwithstanding the existence of well-developed ocelli in many species of free Nematoids, both EBERTH and myself have been quite unable to detect any nerve-filaments in connexion with them, or in fact any certain evidence of the presence of a nervous system in these animals. That such a system does exist I have not the smallest doubt; and considering the difficulties besetting its recognition even in large species of parasitic Nematoids, I think that our failure hitherto in demonstrating its existence in these comparatively minute animals is after all, notwithstanding their transparency, no very great cause for wonder.

I have lately, in examining some of these animals with a $\frac{1}{25}''$ object-glass, detected some almost invisible fibres surrounding the œsophagus. I have recognized them distinctly in *Monhystera stagnalis* and in *Plectus parietinus.* In this last species they are situated, too, just anterior to the orifice of the ventral gland. I think it very probable that this may be its nervous œsophageal band, but cannot speak more positively on the subject.

* Bericht über der Leistungen in der Naturgeschichte der niederen Thiere für 1859, und Untersuch. über *Trich. spiralis*, S. 48.

† Untersuch. über Nemat. S. 51.

‡ *Loc. cit.* Taf. ix.

ORGANS OF SENSE.

The bodies most unmistakeably coming under this denomination in the Nematoids are the ocelli so frequently met with in the free species, and of these, almost exclusively in the marine types. As yet I have only encountered a structure of this kind in one land or freshwater species, namely, *Monhystera vulgaris*. As a rule these bodies are somewhat conical aggregations of reddish-coloured pigment-granules, generally two in number, situated on the dorsal surface of the anterior part of the œsophagus, and exhibiting no refracting portion answering to a cornea or lens, though different species may be found to deviate from every one of these common characters, some in one respect and some in another*. Thus in EBERTH's *Enoplus cœruleus* they are of a blue colour; in the genus *Enchelidium* there is generally one very large pigment-heap almost surrounding the œsophagus, of a brownish colour, in the front of which are three or four clear lentil-shaped bodies or lenses; in *Phanoderma* the pigment-heaps are well-marked, lateral, conical aggregations of bright vermilion-coloured pigment. Where present, in the genus *Cyatholaimus* they are irregular quadrate masses of a brownish-red colour, whilst in the freshwater species above mentioned there is only one small bright-red mass on the dorsum of the œsophagus. In the genus *Leptosomatum* there are two conical masses of red pigmênt on the dorsum of the œsophagus, each having a single lentil imbedded anteriorly (Plate XXVII. fig. 33). In all the cases just mentioned the pigment appears to be situated externally to the sheath of the œsophagus; but in the genus *Enoplus*, and in two or three species of *Oncholaimus*, there seems to be an increased aggregation of pigment-granules into ocelli-like masses in the cervical region of the animal, these aggregations being situated beneath the bounding membrane of the œsophagus, within its walls, and being constituted of the same kind of pigment-granules that may be found scattered more sparingly throughout the rest of the œsophagus. These internal pigment-heaps I propose to call *pseud-ocelli*; they are, doubtless, the early foreshadowings of the more perfect organs; and accordingly, in one species of the genus *Enoplus* (*E. inermis*), I have not found the rudimentary organs similar to those existing in most other species, but what appear to be two distinct pigment-heaps on the external surface of the œsophagus—this organ itself being almost free from scattered pigment-granules. The ocelli are very inconstant organs; they seem present or absent in the same genus according to the requirements of the different species; thus, in some species of *Cyatholaimus* living in marine mud they are absent, whilst they are present in other members of the same genus tenanting the smaller weeds of tide pools.

As before stated no nerve-filaments have ever been actually traced in communication with these ocelli.

The so-called copulatory papillæ in the ventral region of male *Ascarides* and many other kinds of Nematoids, are I believe principally tactile organs, and I have little

* Illustrations of these various modifications of the ocelli may be found in EBERTH's 'Untersuch. über Nemat.,' and also in my "Monograph on the *Anguillulidæ*," Trans. of Linn. Soc. vol. xxv.

doubt that the four papillæ on the cephalic lobes of the *Ascarides* are also sense-organs of some sort, either simply tactile in their nature, or perchance endowed with the faculty of recognizing qualities in bodies different from those which we are capable of appreciating by any of our five senses. No nerve-filaments have yet been traced to either kind of papillæ, and whether or not they have any suctorial properties seems a matter of uncertainty. Concerning what SCHNEIDER has termed the "cervical and caudal papillæ" in the lateral regions of the body, I have already spoken. It seems to me by no means unlikely that the head-lobes themselves in the *Ascarides* are principally tactile appendages, a very large quantity of nerve-fibres pass into them, and in their substance they show a reticulated network of fibres of some kind (Plate XXIV. *l*, *l*, *m*), which I suspect are in great part nervous.

ORGANS OF DIGESTION.

The alimentary canal in the Nematoids is usually a simple, unconvoluted tube, extending through the body in the parasitic species from the terminal mouth to an anus also terminal, or situated but a very short distance from the posterior extremity of the body. In many of the free Nematoids, however, the posterior extremity of the body extends for a considerable distance behind the anus. This tube is always divisible into two distinct portions, an anterior œsophageal part (separated from the next by a constriction), which may be either simple or provided with one or more swellings in its course, and having walls either strongly muscular or for the most part cellular; and a posterior part or intestine proper, with no appreciable muscular tissue in its walls, but always having a more or less developed cellular sheath, performing probably an hepatic function. The length of the œsophagus, as compared with that of the body of the animal, varies much in different species, though as a general rule it is proportionally longer in the free than in the parasitic species. In the former it frequently occupies one-sixth or one-fifth of the whole length of the body, and in *Sphærolaimus hirsutus* as much as one-third, whilst in the parasitic species it frequently does not occupy more than from $\frac{1}{20}$ to $\frac{1}{30}$ of the length of the body, and in many species of *Filaria* even less than this. There are exceptions, however, to this rule met with in the genera *Trichocephalus* and *Trichosoma*, which are most notable for the length of the œsophageal portion of the body; in this respect, as well as in the structure of their œsophagus and many other points in their anatomy, these animals show decided affinities to the free Nematoids, although in some other respects they are widely different.

The *oral opening* in the Nematoids seems most frequently to be triradiate, as it is in the members of the genus *Ascaris*, though in some species of the parasitic and in many of the free animals it appears to be circular. So far as I have seen, it is always terminal and situated in the centre of the anterior extremity.

A *pharyngeal cavity* is rather the exception than the rule, though it exists to a well-marked degree amongst the parasitic Nematoids in the genera *Cucullanus*, *Sclerostomum*,

Angiostoma, *Syngamus*, and *Anchylostoma*, whilst it is long and cylindrical in *Dispharagus*, and rudimentary in the genera *Heterakis*, *Stenodes*, *Stenurus*, *Spiroptera*, and *Strongylus*. In all, this cavity is lined with more or less strong chitinous walls, more developed in some situations than in others, so as to form horny plates or even tooth-like projections. The horny plates may be well seen in the members of the genus *Cucullanus*. In *Anchylostoma duodenale*, according to KÜCHENMEISTER, there are four strong teeth projecting from the upper wall of the pharynx, whilst SIEBOLD describes the entrance to the pharyngeal cavity in *Strongylus armatus*, *S. hypostomus*, *S. dentatus*, and *S. tetracanthus* as "garnie d'un cercle de dents cornées," and adds, "il existe des muscles spéciaux pour les mettre en mouvement." Amongst the free Nematoids*, the most distinct pharyngeal cavities with horny capsules exist in the genera *Mononchus* and *Oncholaimus*, the former having one tooth-like projection and the latter three; it is rather long and cylindrical in *Rhabditis*, somewhat pear-shaped in *Sphærolaimus*, cup-shaped with horny projections from its base in *Diplogaster*, and exists with more flexuous walls in the genera *Linhomœus*, *Cyatholaimus*, *Spilophora*, and *Chromadora*. In the last two genera three horny apophyses extend backwards from the pharyngeal cavity, which are extremely well developed in *Spilophora robusta*. In the genus *Enoplus* three well-marked and separate teeth exist in the pharyngeal region, though I have never been able to make out their exact relationship to the commencement of the alimentary canal. In the genus *Dorylaimus* the pharynx is modified into a strong hollow spear-like body, and can be protruded for some distance from the mouth by means of special muscles (Plate XXVIII. fig. 3) which move it in common with the anterior part of the œsophagus. In all immature species of this genus, a reserve spear exists in the substance of the œsophagus a short distance behind, and of a slightly larger size than the one *in situ*, whose place it subsequently takes. I shall refer to this subject again in the section on development. In the genera *Aphelenchus* and *Tylenchus* a spear-shaped horny pharynx also exists, simple in the former, but having a trilobed base in the latter, though in neither of them is there present the reserve spear met with in the *Dorylaimi*. Most likely these spears are exsertile also, though I cannot speak from actual observation; they suggest a resemblance to the "sharply-pointed dentule"†, capable of being exserted from the mouth in some species of the genus *Mermis*, whilst what is met with in the *Dorylaimi* recalls the principal and reserve proboscideal spines in the members of the genus *Tetrastemma*‡ and other of the *Nemertidæ*.

In those species in which no pharyngeal cavity exists, the mouth communicates at once with the *œsophagus*. Besides innumerable variations in detail, two principal modifications in the nature of this portion of the alimentary canal are met with in the Nematoids, inasmuch as in nearly all the parasitic forms, and in about one-half of the free species, it has a well-developed muscular structure, whilst in the genera *Trichina*, *Tri-*

* The different modifications now to be mentioned are figured, and described more fully in the "Monograph on the *Anguillulidæ*," Trans. of Linn. Soc. vol. xxv.

† COBBOLD, Entozoa, 1864, p. 61.

‡ CARUS, Icon. Zootom. tab. viii. 10.

chocephalus, and *Trichosoma* amongst the parasitic, and the remainder of the free Nematoids, its walls are more or less distinctly cellular, and no muscular fibres can be detected.

The *Ascarides* afford good examples of the simple muscular* œsophagus met with in so many Nematoids, and its structure may at once be recognized by the examination of their transverse sections (Plate XXV. fig. 3). We see then a circular section having a thin structureless bounding wall, whilst internally there is a narrow triradiate cavity bounded by a strong chitinous membrane, between which and the external walls are seen on all sides a series of radiating close-set muscular fibres. By the simultaneous contraction of these the narrow triradiate passage would be converted into a wide triangular canal. If the plains of the radii were prolonged they would be found to alternate in position with the cephalic lobes, one pointing to the mid-ventral region, and the two others upwards and outwards in opposite directions. In certain Nematoids an appearance of longitudinal bands is seen along the axis of the œsophagus. This is met with in the genus *Cucullanus*, and a transverse section (Plate XXVII. fig. 13, *d*) at once reveals their nature, showing them to be produced by six thickenings of the internal chitinous lining of the œsophagus. Similar formations exist among the free Nematoids, and are most marked in *Sphærolaimus hirsutus*. Two or three species of the genus *Ascaris* exhibit a cæcal prolongation of the œsophagus, extending backwards for a short distance along the side of the intestine; this I have seen in the so-called *Filaria piscium*† of the Haddock, and in *Ascaris spiculigera*, and it exists in other species. In these two animals also a cæcal prolongation of the intestine extends forwards (Plate XXII. fig. 9 *a* & *b*), whilst in *A. osculata* the intestinal prolongation alone is present. Nothing definite can be said concerning their use. In the genus *Trilobus*, amongst the free Nematoids, the three lobe-like prolongations at the termination of the œsophagus seem to be developments of much the same nature, and so also, in all probability, are the four glandular bodies in the same region spoken of by De Quatrefages as existing in his genus *Hemipsilus*. The solid, though bright and almost homogeneous ring surrounding the œsophagus in many of the free and some of the parasitic species has already been mentioned in speaking of the nervous system. Amongst the free Nematoids it is very well marked in the members of some of the marine genera, such as *Leptosomatum* (Plate XXVIII. fig. 33, *b*), *Phanoderma*, *Symplocostoma*, and *Oncholaimus*. What its real nature may be is quite problematical both to Eberth and myself. It may be glandular, but no positive statement can be made, save that it does not appear to belong to the nervous system. In the land and freshwater species it seems absent altogether, and the same is the case with a large proportion of the marine forms. Many Nematoids having a muscular œsophagus present one or more swellings in its course. As a rule this swelling, when it

* Although Professor Owen in his 'Lect. on Comp. Anat.' 1855, p. 104, alludes without *dissent* to the opinion expressed by Cloquet, that "the thickened *glandular* parietes of the œsophagus in the *Ascaris lumbricoides* may provide a secretion analogous to that of salivary organs."

† This animal, as it exists in the Haddock, at all events is a young *Ascaris*; reasons for this statement will be advanced further on in the section on development.

exists, is terminal, though in some species another may be present near the middle of the œsophagus, or one in this situation may be the only swelling met with. These enlargements, again, may be either simple developments of the muscular walls, or in addition they may contain in their interior a more or less complex apparatus of horny chitinous plates. The simple terminal swelling may be seen amongst the free Nematoids in the genus *Spira*, whilst horny plates of gradually increasing complexity are seen in the genera *Aphelenchus*, *Cephalobus*, *Anguillula*, *Rhabditis*, and *Plectus*, and to continue the series amongst the parasitic species, in *Heterakis*, *Oxyuris*, and many others. In *Rhabditis* there is in addition a simple, central, elongated swelling, whilst a somewhat globular enlargement exists in this region only in the genera *Tylenchus* and *Diplogaster* *.

The terminal developments have generally been named and described as stomachs, the internal horny plates being looked upon as a kind of teeth, but, as I have on a former occasion pointed out, there seems little warrant for this belief. No dilatations of the central cavity of the organ are met with in these situations, merely an hypertrophied condition of the muscular walls, and the horny plates, instead of being called "tooth-like, crushing organs" †, should, I think, be considered as rather valvular in their nature; the whole apparatus being principally destined to facilitate the taking of food, though partly, perhaps, also more effectually to prevent the regurgitation of the intestinal contents during the movements of the animal. The Nematoids have no prehensile organs of any kind, and their food is, I believe, principally taken by a process of suction. The simultaneous or successive contraction of the transverse radiating fibres, throughout the length of the œsophagus, producing a dilatation of its central canal would cause an inrush of any food or fluid matter to which the mouth might be applied. I have often seen the passage of fluid along the œsophagus of the free Nematoids in this way; the muscles contract with the greatest rapidity, and in *Rhabditis marina* I have seen the valvular plates open and shut just as quickly to give passage to the fluid. Whether the tooth-like projections from the pharyngeal cavity in the *Oncholaimi* are capable of movement I cannot say; I, at least, have never seen them move, and they appear closely adherent to the walls of their enclosing cavity. In *Tylenchus* and *Aphelenchus* the lumen of the œsophagus is very narrow, and apparently stiff and cord-like in external appearance. This misled DAVAINE, so that he did not recognize its real nature in *Tylenchus tritici*, but spoke of it as "un filament simple, tres distinct, semblable à une fibre de tissu élastique" proceeding from the stylet, and whose object he thought was "de donner de la force et de la résistance à l'extrémité antérieure de l'animal" ‡.

The best examples of the cellular or glandular structure of the œsophagus are met with in the genera *Trichosoma* and *Trichocephalus*, and in *Trichina spiralis*, though I am unable to agree with EBERTH with regard to some of the details of their anatomy. The first portion of the œsophagus behind the mouth, in these animals, is different from the remainder, it is narrow, and seems to have granular rather than cellular contents.

* See "Monograph on the Anguillulidæ" for figures. † COBBOLD, Entozoa, p. 367.

‡ Recherches sur l'Anguillule du blé niellé, 1857, p. 24.

It has been named by LEUCKART "mouth intestine" (Munddarm). Throughout the rest of its extent, so far as I can understand EBERTH'S description*, he says the œsophagus is enclosed by a cellular organ which surrounds it on three sides, as an incomplete channel, leaving only the ventral surface free, and he looks upon this organ as a special glandular body, though unfortunately he says nothing further with regard to the actual structure of the œsophagus within the cellular development. I do not know what LEUCKART'S views upon the subject are, but to me it appears almost certain that, although more or less constricted at intervals, the œsophagus in all these animals may be considered a cylindrical organ with a central axial lumen, the ordinary transverse radiating muscular fibres being almost wholly replaced by large nucleated cells with granular contents (Plate XXVII. figs. 18 & 19). Whether muscular fibres exist or not seems very doubtful; I have never seen any, neither does EBERTH speak of their presence. The section of the lumen in *Trichocephalus affinis* seemed to me to have a somewhat triangular form. In *Trichosoma longicolle* all the posterior portion of the œsophagus is divided into elongated compartments by constrictions at intervals (Plate XXVII. fig. 14). Near the centre of each compartment there appears a clear spherical mass with no very defined bounding wall, whilst along the crenated margins a series of similar though much smaller bodies exist, which are in all probability nucleoli enclosed within an outer cell-wall, as are the similar bodies met with in the œsophagus of *Trichocephalus affinis* (Plate XXVII. fig. 19). In this latter animal the rounded or crenated borders are still better marked, and the cellular body with its enclosed spot seen opposite each crenation, are in all probability the nucleus and nucleolus of a still larger granule-containing cell whose walls are indistinct. In a very thin section which I succeeded in making of this animal at about the termination of the anterior third of the œsophagus, this organ was seen to fill almost the whole width of the cavity of the body (Plate XXVII. fig. 18), and to be made up entirely of an aggregation of nucleated cells, each densely filled with granules, surrounding the small somewhat triangular central lumen. I need not describe here the processes of a somewhat triangular shape, passing from the parietal muscles of the body to the constricted portions of the œsophagus, which are met with throughout a great part of its length, and act as a series of mesenteric processes, since most observers are agreed as to their presence and nature. In the *Trichocephalus affinis*, although no demarcation of the œsophagus into large segments exists similar to what I have described in *Trichosoma longicolle*, yet there do exist large cellular bodies at pretty regular intervals, which seem homologous with the clear non-granular mass present within each segment of the œsophagus in the latter animal. Their structure is, however, different, since in *T. affinis* it consists of a clear cell with no defined contents, save an excentric granular nucleus with its contained nucleolus. These are very well marked towards the posterior extremity of the œsophagus. In the *Trichocephali* and *Trichosomata*, generally on either side of the termination of the œsophagus, there is a pear-shaped or more elongated prolongation directed

* Untersuch. über Nemat. p. 50.

forwards, such as I have represented in Plate XXVII. fig. 14, *c*. It is often of a yellowish colour, and sometimes no nucleus can be detected. KÜCHENMEISTER mentions these bodies in his description of *Trichocephalus dispar*, and EBERTH says he has found them in every species examined. For further details concerning the œsophagus and other parts of the animals included in this division of the Nematoids, I must refer to Dr EBERTH's most interesting memoir and beautifully executed figures.

Amongst the free Nematoids there are a large proportion of the species which do not present a well-marked muscular œsophagus, and among them the best examples I can cite are the members of the genera *Phanoderma*, *Leptosomatum*, *Enoplus*, *Oncholaimus*, *Chromadora*, and *Dorylaimus*. I might name several other genera, but those just given contain species of the largest kind, and are therefore best fitted for examination. In the first five genera, which are marine, a quantity of pigment-granules are generally present, more or less thickly interspersed in the substance of the œsophageal walls, and by means of a rather thick section of the œsophageal region of the body of an *Enoplus communis* I was enabled to ascertain that the œsophagus itself was cylindrical, and had the characteristic triradiate lumen in its centre, and that moreover the olive-coloured pigment was principally arranged along three longitudinal lines, corresponding closely in position with the apices of these three radii. What, however, the exact histological structure of the œsophageal walls may be I am unable to say; in the genera above mentioned it certainly presents no well-marked granular cells, such as have been described in the *Trichocephali* and allied animals. EBERTH* also seems to have been much puzzled by the structure of the œsophagus in some of these animals, and is able to throw but little light upon the subject. In *Phanoderma Cocksi* and other members of the same genus, there are three longitudinal rows of bright orange-coloured pigment-granules, and the posterior widening half of the œsophagus is constricted at pretty regular intervals, so as to give its borders a crenated appearance, very much resembling what we find in *Trichina spiralis* and the *Trichocephali*. From the cut extremity of the œsophagus in *Dorylaimus stagnalis* I have seen a number of small hyaline cells of varying size (Plate XXVII. fig. 5) issue, but with this exception have never been able to detect well-marked cells in the œsophageal walls of any of the free Nematoids. All that I have been able to make out was a kind of clear, gelatinous, undifferentiated tissue containing in its substance large, interspersed, pigment-granules. It is possible that this substance may be a kind of contractile sarcode—at all events it seemed very consistent and somewhat elastic. In the various species of the genus *Enoplus* a number of bright lines or linear spaces exist, having a transverse direction, though what the exact nature of these structures may be I have been unable to ascertain. These cross stripings have also attracted the attention of EBERTH and BERLIN†.

Judging from what I observed formerly of the structure of the œsophagus in the Guineaworm, I should imagine that it must have been originally an organ with cellular parietes, the disintegration of which would account for the quantity of granular matter

* Untersuch. über Nemat. 1863, p. 9.

† MÜLLER's Archiv, 1853.

contained within its sheath, and the isolated condition of what should have been its axial lumen or canal. In this animal, lining the inner side of the sheath of the œsophagus, was a longitudinal layer of fibres apparently muscular* in their nature. This is the only Nematoid in which such fibres have yet been recognized.

The remaining or *intestinal* portion of the alimentary canal is subject to much less variation, and its essential structure is the same in all Nematoids. It is separated by a well-marked constriction, as well as by a difference of tissue, from the œsophagus, being composed of an external structureless membrane, bounded internally by a more or less developed layer of cells, each of which contains a clear nucleus-like body and a number of dark spherical particles†. The nucleus very frequently appears to be absent, though this may be owing to its being obscured by the pigmentary particles; and where present it often appears only as a clear space free from granules (Plate XXVIII. figs. 6, 10, & 29). Internally the cells are bounded by a kind of structureless cuticle, which perhaps is not an independent formation, but is produced by a thickening of the walls of the cells next the central cavity. In *Ascaris lumbricoides* and many other species of the same genus, these intestinal cells are long and columnar, and when an isolated portion of intestine is spread out and examined through its outer membrane, the hexagonal bases of these cells may be seen, presenting a regular tessellated appearance (Plate XXIII. figs. 10 & 11). These cells are very long in *A. megalocephala* and *A. mystax*, and in this last animal the internal cuticle is very thick and well developed (Plate XXVI. fig. 5). The cuticle is distinct also in *A. osculata*, whilst in many of the free Nematoids it forms an inner tube quite distinct, and capable of being isolated from the outer and the intervening cellular layer; this may be well seen in the members of the genera *Tylenchus*, *Aphelenchus*, and *Monhystera* (Plate XXVIII. fig. 28). In *A. osculata*, as well as in *A. spiculigera* and *Filaria piscium* from the Haddock, I have found the cavity of the intestine almost obliterated by the great development of the cellular layer, and its projection inwards in the form of large rounded masses (Plate XXVI. fig. 10); some of the cells composing them are elongated, though for the most part they have a rounded form. I have seen similar nodosities of the cellular layer at the posterior part of the intestine in *A. megalocephala*. In several *Strongyli* that I have examined I have found the intestinal granules very large and somewhat light coloured, though I have not been able to detect the separate cells in which the granules are contained, and the same difficulty occurs with many other Nematoids. This cellular or glandular layer is described by DUJARDIN as being "d'un rouge vif" colour in *Filaria labiata*, though in other animals it seems to vary from a whitish to an almost black colour, the predominant tint being olive-brown. In some species the cells are of a rounded shape, and this, allowing for

* Trans. of Linn. Soc. vol. xxiv. p. 116.

† These particles, when liberated by rupture of the cells, generally exhibit an active molecular movement; I have often watched for evidences of this movement in the unruptured cells, but have always failed except on one occasion, and then I witnessed a most active molecular movement within the cells of a portion of intestine which had been expressed from the cavity of the body of one of the freshwater species of the free Nematoids.

alterations by mutual pressure, seems generally to be the form in the free Nematoids, together with the *Trichocephali* and their allies. In these animals the separate cells are often most distinct, and with their fellows produce a well-marked tessellated appearance, though in others the boundaries of the several cells cannot be recognized, and an intestinal sheath of thickly disposed granules is all that can be detected. The separate cells are very small in *Enoplus Dujardinii*, and very large in *Monhystera ambigua* and *M. disjuncta**, whilst they appeared almost absent, or at least free from granules, in *Spilophora costata*, and in some specimens of *Leptosomatum elongatum*. In *Symplocostoma longicolle* the arrangement of the cellular layer in old specimens is often most irregular.

According to EBERTH a well-marked cuticle exists bounding the cells internally in *Sclerostomum dentatum*, as well as in *Strongylus commutatus* and *S. tenuis*; whilst in the *Trichocephali* he says he has seen this, after the application of water, appear to be composed of a closely-packed row of little rod-like bodies. He further says that towards the end of the intestinal canal of the latter animals, he has recognized transverse muscular fibres in the larger species.

The terminal portion of the intestine, which some have named the rectum, loses the cellular layer, contracts in calibre, and appears for some distance to be encircled externally by muscular fibres, which probably have a sphinteric function (Plate XXV. figs. 5, *b*), and with which, also, certain other muscular fasciculi, passing to the walls of the body and having a dilating function, are connected. The structureless walls of the rectum are continuous at the transverse anal cleft with the chitinous integument, so that we may perhaps consider the structureless bounding membrane of the intestine to be a modification of this tissue.

Hitherto many doubts have been entertained as to whether or not an anal orifice existed in the Guineaworm (*Dracunculus medinensis*), and in my paper on the anatomy of that animal, I stated that I had traced the intestinal canal to what appeared to be its termination close to the posterior extremity of the animal, in the centre of the great ventral, longitudinal muscular band—corresponding pretty closely in situation to the place where RUDOLF WAGNER stated that he had seen an actual aperture through the integument. I have lately examined other well-preserved specimens of this animal, and have succeeded in detecting a minute aperture through the integument opposite the position to which I again traced the termination of the intestine internally (Plate XXVII. fig. 20, *a*). This aperture is, however, altogether abortive, and by no means proportionate in size to that met with in other Nematoids. Indeed the development of the intestinal canal as a whole appears by no means to have kept pace with the development of other parts of the body. The termination of the alimentary canal is fixed in position by fibres passing to it from the lateral intermuscular spaces of the animal. In the embryos of one of these other specimens of *Dracunculus* that I have lately examined, which seemed to be in a more developed condition than any I had before met with, I distinctly found the intestine provided with an anal aperture slightly anterior to the level of the lateral

* Trans. of Linn. Soc. vol. xxv. pls. ix. & xii.

sacculi (Plate XXVII. fig. 22), in much the same position as it was represented to exist by CARTER*.

In the Nematoids generally, the intestine is bound to the parietes of the body by more or less developed retinacula, which are usually delicate prolongations from the longitudinal muscles.

The cellular layer lining the intestine has in all probability a glandular function to perform, and its share in the process of assimilation may perhaps entitle it to be looked upon as possessing a rudimentary *hepatic* function. Such seems to be the general opinion as to its nature.

With regard to the food of the parasitic Nematoids, a great difference exists according to the particular parts of the body of their respective hosts which they are in the habit of frequenting, and it seems reasonable to expect that differences in organization might be met with amongst these species, in a measure coincident with the degree of elaboration of the fluids upon which the respective animals feed. We seem to be able to recognize this to a certain extent, since in *Prosthecosacter inflexus*, inhabiting the heart and vascular sinuses of the Porpoise, and consequently drawing its nourishment from a fluid already much elaborated, I have found a low development of the glandular structures of the body; whilst in the *Ascarides*, such as *A. spiculigera* from the stomach of a Cormorant, or *A. osculata* from the intestines of the Seal, feeding upon less elaborated materials, we have seen the enormous development of the glandular hepatic lining of the intestine; and in *A. lumbricoides* we meet with an enormous development of the glandular portions of the muscles in the form of bladder-like prolongations, constituting the "appendices nourriciers" of CLOQUET.

In the "Monograph on the Anguillulidæ"†, I have mentioned a few particulars concerning the food of the free Nematoids, and have also alluded to the occasional large quantity of fat met with within the alimentary canal of these animals, apparently as a primary product in the process of assimilation.

GLANDULAR SYSTEM.

The glandular system, under various forms, is extremely well developed in the Nematoids, and seems to fulfil a most important function in their economy.

A series of floating gland-cells exists in variable quantities suspended in the fluid contents of the general cavity of the body, which may be considered analogous at least to the blood-cells or corpuscles of higher animals. The fluid in which they float is mostly colourless, though in some Nematoids, as in *Syngamus trachealis*, it is of a blood-red colour. The cells themselves vary much in size as well as in number. In *Ascaris lumbricoides* they may be found in the fresh dead animal aggregated together in minute masses in the cavity of the body, the cells themselves being about $\frac{1}{3500}''$ in diameter and of a somewhat light-olive colour (Plate XXIII. fig. 12). In many of the free

* Annals of Nat. Hist. Ser. 3, vol. iv. (1859) pl. 1, fig. 6.

† *Loc. cit.* p. 84.

Nematoids these cells seem to be almost absent, or are so small as scarcely to deserve any other appellation than granules, whilst in others they are larger and more abundant. Unusually large bodies of this nature, with a distinct nucleus, are frequently seen within specimens of *Leptosomatum figuratum* (Plate XXVII. fig. 31).

The cellular or medullary portion of the muscle-cells which have been before described, may, in all probability, be justly considered as glandular elements; and under this head I should include the structures previously mentioned as existing in connexion with the muscles of *Symplocostoma longicolle*, and which are apparently homologous with the cellular structures so abundantly met with in many of the other free Nematoids. These glandular formations on the surface of the muscle are generally most marked at the anterior and posterior extremities of the body, and seem to attain their maximum development, so far as I have seen, in the various species of the genera *Leptosomatum* and *Phanoderma*.

The glandular nature of the cellular mass lining the intestine has just been spoken of in the concluding portion of the last section.

Professor OWEN* has described structures which he considers to be analogous to salivary organs, "consisting of four small slender blind tubes, each about two lines in length, which are placed at equal distances around the commencement of the alimentary canal in the *Gnathostoma spinigerum*, a small Nematoid worm closely allied to *Strongylus*," which he discovered in the tunics of the stomach of a tiger. These tubes he seemed to think emptied their secretion into the mouth. EBERTH has described and figured two small glandular bodies in connexion with the large pharyngeal cavity of *Enoplus cœruleus*. Each of these is rather elongated in form and provided with a nucleus, and he thinks may open into the pharynx anteriorly.

Glandular bodies are present in connexion with the termination of the intestine in many Nematoids, both free and parasitic. These have been carefully described and figured by EBERTH in many species, and though, curiously enough, he seems quite to have made up his mind as to their nature when existing in the free Nematoids, by the fact of his having given them the name of "anal glands," still when he meets with similar structures in the parasitic species he seems to dally with the idea that they may perchance belong to the nervous system, seemingly led away in this manner by the misconceptions into which WALTER had fallen concerning the nervous system of *Oxyuris ornata*, an animal in which anal glands appear to be present. These structures WALTER still persists in believing should be considered as central ganglia of a nervous system.

I have met with these anal glands amongst the free Nematoids in the genera *Anticoma*, *Linhomœus*, and *Cyatholaimus*. They consist of from two to four finely granular masses, varying in shape and size, each having a clear central nucleus-like body, which may when small, as in the genus *Anticoma*, be in close connexion with the rectal portion of the intestine, or if larger may occupy much of the cavity of the body between this and the posterior extremity. EBERTH has also figured these bodies, but we have neither of

* Lect. on Comp. Anat. of Invert. 2nd Ed. 1855, p. 103.

us been able to ascertain what are their exact connexions, or whether they are provided with excretory canals. I have seen similar structures in two or three species of *Strongyli* and in *Heterakis acuminata*, whilst they have also been met with, as well as figured, by EBERTH, in *Oxyuris ambigua* and *Heterakis vesicularis*. In these various parasitic species their number and arrangement is different, though their essential nature is the same; they present the appearance of granular nucleated bodies variously arranged around the termination of the intestine, and connected with it by pedicles, which very probably are excretory ducts.

Another description of gland exists in connexion with the vagina in the females of certain species of free Nematoids, which have been called "vaginal glands." In histological structure and appearance they are very similar to the anal glands just described. They are stalked, often pyriform in shape, having finely granular contents, and may or may not show the same bright central body or nucleus. They are connected with the vagina close to its external aperture. EBERTH has discovered four such bodies in his *Enoplus tuberculatus**, and two in his *Enoplus gracilis*, whilst in *Enoplus megopthalmus*, where he has also met with them, they present a different character, and consist of two pear-shaped masses seemingly composed of an aggregation of nuclei†. I have met with two equal, stalked, pear-shaped glands in *Symplocostoma vivipara*, one anterior and the other posterior; a similar position of two unequal glands in *Tachyhodites velox*; and one large posterior gland only in *Sphærolaimus hirsutus*‡.

I am aware of only one species of parasitic Nematoid in which such organs are to be met with, and this is in *Heterakis vesicularis*, in which EBERTH has represented§ three stalked, pear-shaped, glandular bodies in connexion with the anterior wall of the vagina‖.

* Really *Phanoderma tuberculatum*.

† Unters. über Nemat. Taf. ii. 24.

‡ For figures see 'Monograph on Anguillulidæ.'

§ Würzb. Naturwissensch. Zeitsch. 1860, Erst. Bd. Taf. iii. 21.

‖ Before dismissing the subject of the glandular and secretory organs of these animals, this seems a suitable place for me to record some of the remarkable effects invariably produced upon myself whilst working at the anatomy of *Ascaris megalocephala* from the Horse. Emanations from this animal had the most decided and poisonous influence upon me, and this not only when the animal was in the fresh state, but after it had been preserved in methylated spirit for two years, and even then macerated in a solution of chloride of lime for several hours before it was submitted to examination. I first examined this species in the spring of 1863, when certain strange effects were produced which I was enabled to trace absolutely to the fact of my working with this animal. These were a greatly increased secretion from the Schneiderian membrane, with irritation of it, causing continuous sneezing, also irritation of the conjunctiva, with such a sense of itching about the eyelids and caruncula lachrymalis as to make it extremely difficult to abstain from rubbing them. When they were rubbed this immediately gave rise to a swollen and puffed condition of the eyelids, swelling of the caruncula, and extreme vascular injection of the conjunctiva, and if the rubbing was at all persisted in, actual effusion of fluid would take place under the conjunctiva, raising it from the subjacent sclerotic and cornea. A few minutes would suffice to produce these serious effects upon the eyes, but after a little bathing with cold water, and rest in the recumbent position for a couple of hours, they would have again resumed their natural condition. At the same time that these effects were produced upon the mucous membranes, the skin of the face and neck was also affected, so as to cause a sensation of itching something similar to what exists in a mild attack of nettle-rash. If I continued

ORGANS OF CIRCULATION.—WATER-VASCULAR SYSTEM. "LATERAL AND MEDIAN LINES."

Von SIEBOLD was the first to describe* an excretory system in the Nematoids having a mid-ventral opening in the anterior part of the body. In his 'Manuel' he speaks of this discovery thus:—"Chez plusieurs Nématodes, on observe, à la face ventrale et à une plus ou moins grande distance de l'extrémité cephalique, une petite fente transversale entourée d'un sphincter. Chez quelques espèces, il en part deux canaux intestinaux, et qui, chez d'autres, sont accompagnés de deux autres canaux qui se portent en avant. Les usages de la matière incolore et homogène sécrétée par ces organes ne sont pas encore connus" (p. 140). Since the date of SIEBOLD'S first observation, no great accession to our knowledge concerning these structures has been hitherto made, and the opening in the

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to work for about two hours in spite of these symptoms, a general feeling of lassitude and weariness was produced, sometimes amounting to an actual sense of prostration, which would, however, all pass off on desisting from the work and lying down for a few hours. After a few weeks another symptom was superadded, in the form of an asthmatic difficulty of breathing, owing apparently to a constriction of the trachea and of the larger bronchial tubes, which was first noticed about one o'clock one night shortly after going to bed. Without any warning I felt a kind of constriction of the upper air-passages with great difficulty of breathing, each inspiration and expiration being accompanied by an almost musical wheezing sound. This lasted for about three quarters of an hour, when there came a gradual relaxation of the spasm, and all was well again. Such attacks as these gradually became more frequent, generally occurring in the night or evening, lasting longer and often associated with a spasmodic cough, so that much against my inclination I was at last compelled to abstain from any further examination of these noxious individuals. My system at length became so sensitive to the emanations of this animal that I was even unable to wear a coat which I had generally worn during these investigations, without continually sneezing and suffering from other catarrhal symptoms. Avoiding this and other sources of irritation, after a period of about two months every vestige of these symptoms had disappeared, and continued absent till May 1864. During this interval I had never looked at a specimen of *A. megalocephala*, neither did I once experience any of the old asthmatic difficulty of breathing. For one day in the beginning of May I did work with this animal again; not so much sneezing and actual irritation was produced at the time, and I was full of hope, but in the evening came one of the old asthmatic attacks, and the influence produced by this one day's work did not completely exhaust itself till the middle of June—a period of nearly six weeks. During all this intervening time I had been subject to occasional spasms and difficulty of breathing. Subsequent isolated periods of work with this Nematoid have also shown me that it takes from one month to six weeks for its effects entirely to disappear. In the spring of this year I again worked daily with these animals for nearly a month, till the symptoms became so severe as absolutely to compel me to desist. A certain change had come over their influence upon me. I now suffered far less from the more local irritating effects, and much more from the severity of the asthma and spasmodic cough. There was a curious kind of periodicity too about the worst attacks; they generally occurred between five and six o'clock in the morning, and so regularly was this the case that it was almost needless for me to look at my watch, on awaking, to ascertain the hour. These attacks would sometimes last for more than two hours, accompanied by extreme dyspnœa and the most distressing paroxysms of cough. Then at last came a gradual relaxation of the spasm, accompanied by a secretion of thin mucus from the bronchial tubes, followed by an absence of cough and natural breathing for twelve or even twenty-four hours. Not having anatomized these animals since, I have again been entirely free from such symptoms for nearly two months. No effects of this kind were produced by working with *A. lumbricoides*; neither does *A. megalocephala* appear to have affected Dr. SCHNEIDER or other anatomists in the manner I have just been stating.

* In a Dissert. by BAGGE, 'De Evolut. Strong. Auric. et Ascar. acuminat.' 1841, p. 13.

ventral region has been rather a stumbling block to anatomists on account of the different bodies with which it was connected; in some cases it appeared as the exit of a system of tubes, whilst in others it was connected with glandular bodies of different sizes, sometimes single and sometimes double; and lastly, WALTER* almost certainly alluded to the same opening when he spoke of an anterior ventral sucker existing in the young of many Nematoids, which he believed either to retrograde or entirely disappear in the adult animals. There can be little doubt, however, that we may dismiss this statement of WALTER'S at once as being altogether erroneous. And if it be carefully borne in mind that no observer hitherto has ever discovered more than a single aperture in this situation, I think I shall be able to simplify the whole subject, and also be able to advance cogent reasons for the belief that all the various bodies hitherto met with in connexion with this ventral aperture, are only modifications in the development of one common system answering to the so-called "water-vascular system," so well known to exist in the *Trematoda* and other animals.

The most elementary structures met with in connexion with the ventral opening have been figured and described by Dr. LEIDY† in a species of *Hystrignathus*, and by EBERTH‡ in *Ascaris oxyura* and *Oxyuris ambigua*, in which minute saccules are met with, exhibiting a very rudimentary condition of the so-called "ventral gland." Amongst the free Nematoids, in *Cyatholaimus ornatus* (Plate XXVIII. fig. 36), *Sphærolaimus hirsutus*, the members of the genus *Enoplus* and others, we find it slightly more developed, inasmuch as it exists as a tubular organ extending from the ventral aperture near the middle of the œsophagus, to or nearly as far as the termination of that organ. It has granular contents, and its calibre is uniform except at its blind extremity, where it is very slightly enlarged. In *Linhomœus hirsutum* and *L. elongatum* it is a little longer, extending as far as the commencement of the intestine, which is compressed by the more developed condition of its blind termination. This appears of a dilated pear-shaped form, and is filled with granular contents, in which is imbedded a clear, solid, homogeneous looking body or nucleus §. This or the former represents the condition of the ventral gland in most species of the marine Nematoids, and it seems present in almost all the genera. In the land and freshwater species, however, I have recognized a ventral aperture and gland only in the members of four genera, *Aphelenchus*, *Cephalobus*, *Tylenchus* and *Plectus*, and in these it is somewhat modified in form. The duct, instead of being a wide membranous tube, is here a narrow and rather rigid structure, extending with a gentle curve towards the centre of the body, as may be best seen with adult specimens of *Tylenchus tritici* (Plate XXVIII. fig. 17), or having altogether a twisted direction, being two or three times bent upon itself, as occurs in the various species of the genus *Plectus* (Plate XXVIII. fig. 14.). It is extremely difficult to ascertain the precise mode of termination of this duct, but after the most prolonged examinations I am enabled to assert pretty confidently that in *Tylenchus Davainii* this tube communicates with a rather small

* *Vide* KÜCHENMEISTER (Syd. Soc. Transl.), p. 365 and note.

† Smithson. Contrib. 1853.

‡ Untersuch. über Nemat. Taf. viii. 9, 10.

§ *Vide* figures, Trans. of Linn. Soc. vol. xxv.

thin-walled ovoid sac (Plate XXVIII. fig. 20), with no very definite contents *. Probably a somewhat similar structure obtains in all these four genera. EBERTH states that he has seen in some marine Nematoids the ventral gland composed of two similar parts terminating at a common ventral aperture †, which is an arrangement identical with what has now been recognized in many parasitic species. I have seen distinctly in *Strongylus filaria* two elongated glandular bodies, terminating by a short common portion, which opens externally by a single median orifice (Plate XXVII. fig. 8). Each of these bodies has the same structure as the single gland met so commonly amongst the free Nematoids, that is to say it is white in colour and dilated at its posterior extremity, enclosing granular contents and a clear, homogeneous, nucleiform body. These glands are, however, longer, and extend further backwards than any we have yet met with. MEHLIS ‡ appears to have recognized the dilated portions of these organs in *Strongylus hypostomus* as long back as 1831, whilst EBERTH has lately recognized the entire organs in *Strongylus retortæformis*, *S. commutatus*, and *S. striatus*; two posterior tubes were also spoken of by Von SIEBOLD in connexion with the ventral aperture of *Strongylus auricularis*, so that I think we may fairly look upon this as the typical form of the organ in the genus *Strongylus*. Similar organs are described and figured by KÜCHENMEISTER § as existing in *Anchylostomum duodenale*, and by EBERTH ‖ in *Sclerostomum dentatum*, whilst I have myself recognized the outlet and commencement of the tubes in *Sclerostomum equinum* ¶. In *Heterakis acuminata* there is a large transverse opening in the ventral region opposite the termination of the œsophagus which communicates with a dilated termination of the ducts, though I could recognize no distinct ampulla-like body, such as was figured by SCHNEIDER **. This was one of the early species in which two posterior tubes were traced in connexion with the ventral aperture by Von SIEBOLD, which are, I suspect, similar in character to those which we have just been describing. I have also recognized a ventral opening with a large tube proceeding from it in *Heterakis vesicularis*, which I think will very likely prove to be the terminal portion of two similar glandular bodies. This structure does not seem to have been noticed by EBERTH, since he mentions nothing of it in his account of the anatomy of the animal.

* This tube gradually becomes lost to view over the intestine, and DAVAINE (Rech. sur l'Anguill. du blé niellé, 1857) imagined it to be an excretory duct in connexion with the cellular lining of the alimentary canal.

† I have met with quite an exceptional condition of things in *Leptosomatum elongatum*. In this animal there are two lateral tubes extending along by the side of the œsophagus for about two-thirds of its extent, each of which opens by a lateral aperture on either side of the head, close to the mouth (Trans. of Linn. Soc. vol. xxv. pl. xii. fig. 156). In structure each tube much resembles that of a ventral gland, which, however, is absent in this and two or three other allied species at present located in the same genus. Are they homologous with the salivary tubes described by OWEN in *Gnathostoma*?

‡ OKEN's Isis, 1831, p. 81. Taf. ii. fig. 6. MEHLIS thought these organs opened into the mouth, and fancied they poured out an irritating fluid destined to increase the secretion of the mucous membrane to which the animal was attached.

§ Syd. Soc. Translation, 1857, p. 385.

‖ Untersuch. über Nemat. p. 66. Taf. xviii. 3.

¶ The *Strongylus armatus* of many authors, and the *Sclerostomum armatum* of RUDOLPHI and DIESING.

** MÜLLER's Archiv, 1858. Taf. xv. fig. 7.

I have now to notice considerable modifications of this structure met with amongst other Nematoids. CLOQUET* was, I believe, the first to speak of an axial vessel contained within the lateral cords of *Ascaris lumbricoides* and *A. megalocephala.* He describes the colour of these lateral bands, in a manner in accordance with my own observations, as very variable in different individuals, adding, "Quelquefois elles sont blanchâtres ou grises, d'autre fois d'un rouge assez vif† ou d'un brun obscur; mais une chose digne de remarque, c'est que ces couleurs ne sont pas uniformes dans toute leur longueur; que très-faibles dans un endroit, elles ont beaucoup d'intensité dans un autre." He also spoke of each vessel leaving its band anteriorly, "s'anastomoser avec celui du côté opposé, en formant une arcade simple dont la convexité est antérieure, et de laquelle on ne voit sortir aucun filament." Then followed the observations of BLANCHARD‡, who not only recognized but succeeded in injecting these same axial vessels and their anterior communicating branch. He spoke also of an enlargement of the vessel and "une sorte de petite poche" existing on the right side of the arch, which he says "me paraît devoir être considérée comme étant véritablement un vestige de cœur." He maintains also that in each lateral cord there is a second vessel, "très-grêle," lying almost immediately beneath the integument; though he says nothing concerning the anterior distribution of these second vessels or the posterior terminations of either set. He does, however, go so far as to state that this arrangement of the circulatory apparatus is perfectly characteristic of the order *Nematoidea*, since he has been able to recognize it in the most different types. He says, "J'ai examiné les vaisseaux chez les Trichocéphales, les Filaires, les Sclérostomes, les Oxyures, etc.; partout j'ai pu constater une disposition exactement analogue." That this description is incorrect as regards the *Ascarides*, I have not the slightest doubt, and there is even more reason for believing it at variance with what actually exists in the other genera mentioned. The next anatomist who contributed to our knowledge concerning these vessels in *Ascaris megalocephala* and *A. lumbricoides* was Dr. SCHNEIDER §. He ascertained that the arched communication gave off a short straight prolongation in the middle of its course, which brought these vessels into relation with the exterior by means of an aperture in the mid-ventral region a short distance behind the mouth. The figure he gave on this occasion was rather incorrect, though he has since given a much more truthful representation of this arch of the vascular system in a recent paper in the same periodical ||. This representation shows the rudimentary heart of BLANCHARD to be a large cell filled with granules situated in the thickened parietes of the vessel, at the left side of the arch. SCHNEIDER also gives an enlarged representation of one of the lateral bands of *Ascaris megalocephala*, in which he correctly represents the contained vessel situated near the internal surface of the band, and also pourtrays a chink (Spalt) or split

* Sur les Vers Intestinaux, 1824, p. 38.

† This appearance seems due to the colour of the fluid in the axial vessel.

‡ Ann. des Sc. Nat. 3[me] sér. t. vii. (1847) p. 126.

§ MÜLLER's Archiv, 1858, p. 426. Taf. xv. 3 *a*.

|| Idem. 1863. Taf. i.

extending for some distance into its substance* from and in a direction at right angles to the integument, as well as a marked difference in histological structure between the band itself and the granular layer on which he describes it as resting. As regards these latter characters I am unable to agree with SCHNEIDER. I have succeeded in making remarkably thin transverse sections of these lateral bands, both when they were in a moist condition (with a VALENTIN'S knife) and in the dried animal. These sections have been most successful both with *Ascaris megalocephala* and *A. lumbricoides*, and in neither have I been able to recognize the slightest trace of any vessel in the situation mentioned by BLANCHARD, or any natural solution of continuity corresponding to what SCHNEIDER has described. Artificial cracks or fissures are, however, by no means uncommon (which is scarcely to be wondered at considering the nature of the tissue in question), and an examination of the figure Dr. SCHNEIDER has given, is far from discountenancing this view of the possible explanation of what he has represented. With regard to the histological structure of the lateral band, I believe this to be absolutely identical with that of the deep cellulo-granular layer of the integument, and to be in short nothing but an intermuscular development of it. No line of demarcation exists between them, and they both consist of the same elementary constituents (Plate XXIII. figs. 5 & 16), being made up of a dense aggregation of large, highly refractive particles† or granules, together with nucleated cells and a few interspersed fibres. These lateral bands are considerably larger in *A. lumbricoides* than in *A. megalocephala*‡, especially in the anterior parts of the body, and their structure is also denser, owing to a firm fibrous network existing within them, which is most developed next the external integument and extends thence inwards to the longitudinal vessel. This fibrous framework seems to be present principally in the anterior portions of the bands, and does not appear to exist at all in those of *A. megalocephala*. In this latter animal also the contained vessel is not only relatively but absolutely larger than in the last-named species, and may be isolated with ease. Although the arrangement of the vessels or canals in these two species is identical, this can be much better made out in *A. megalocephala*

* EBERTH, I fancy, has followed SCHNEIDER in this particular, and has given a most exaggerated representation of this chink (Spalt), which figure has been introduced by Dr. COBBOLD into his recent work on "Entozoa," at p. 305. I believe EBERTH merely to have followed SCHNEIDER as regards this structure, because he does not appear to have examined this *Ascaris* very fully, and I can find no mention of the structure, except in his explanation of the figure.

† These biscuit-shaped particles have often been spoken of as fat particles, but they are not soluble in a mixture of boiling alcohol and ether, and I suspect their composition would ally them more closely to the protein group of elements (MÜLLER'S Archiv, 1858. Taf. xv. 2).

‡ When the inner surface of the bands of *A. megalocephala* is examined with a lens, it often presents a sort of honeycombed or reticulated aspect for a short distance. In *A. lumbricoides*, especially in the posterior halves of the lateral bands, brownish-coloured patches are frequently seen at intervals, seemingly due to a deposit of pigment in its substance. And in old specimens, when different portions of these cords from the posterior part of the body are submitted to microscopical examination, deposits and deviations from the usual structure are by no means uncommon. SCHNEIDER has represented remarkably large cellular bodies as existing in the substance of the lateral bands of *Ascaris acus*.

than in the other. In *A. lumbricoides* a distinct walled vessel does exist, though its isolation from the surrounding tissue is by no means easy; the arch also is less pronounced. Neither in this species nor in *A. megalocephala* could I see, when viewed from within, the straight exit-tube of the arch; it does not seem to lie along in the median line, but to proceed almost directly *outwards* through the muscular layer and integument to the median aperture, which is I think only very slightly anterior in position to the arch itself. It is not easy to follow these vessels in the lateral bands towards the posterior extremity of the body, but after the most careful examination of individuals of these species and of *A. marginata*, I feel quite confident that no posterior union between the vessels exists, but that in all they appear gradually to diminish in size and in the thickness of their walls, and either disappear or dwindle into mere lacunar channels at about the level of the anus. Thus in a specimen of *A. marginata* one of the thick-walled vessels, just behind the arch, measured $\frac{1}{450}''$ in diameter, having a central lumen $\frac{1}{2000}''$ in diameter, whilst close to the termination of the vessel, where I was fortunate enough to be able to isolate it from the band in which it was imbedded, at a distance of $\frac{3}{4}''$ from the posterior extremity of the animal, the diameter of the entire vessel was only $\frac{1}{5000}''$. I have never been able to detect branches of any kind given off from these lateral canals or vessels. Their walls are composed of a dense tissue; and though I have not been able to make out its exact structure, I have no doubt that it is a kind of muscular tissue, capable of contracting and dilating. Contiguous portions of the canals may frequently be seen with a varying calibre; and on the left side of the arch I have occasionally seen the canal very narrow opposite the peculiar, large, more or less round or ovoid cell, enclosed in its thickened outer wall in this situation (Plate XXV. fig. 9). This body is altogether remarkable; imbedded in the very substance of the wall of the canal it has a distinct bounding membrane and is densely filled with small granules, which generally effectually conceal a clear nuclear body existing in the centre. Curiously enough, too, I have detected three bodies presenting a precisely similar appearance in what I believe to be muscular tissue, surrounding the rectal termination of the intestine in *A. megalocephala* (Plate XXV. fig. 5). What their nature can be I have not the slightest idea, neither have I met anything similar to them elsewhere among the Nematoids. In those *Ascarides* having the above-mentioned arrangement of their excretory tubes, a body of this kind seems always to exist on the left side of the arch, and at the same time the walls of the vessel on this side are generally much thicker than on the other. What relationship there is, however, between these two facts I am unable to say, and it seems very difficult to explain why one side of the arch should be larger than the other. The most extreme divergence between the two sides exists in *A. marginata*, in which animal these canals are remarkable, not only for the thickness of their walls, but also for their great proportionate size as compared with that of their containing bands (Plate XXVI. fig. 2). In *A. mystax*, on the contrary (Plate XXVI. fig. 4), the vessels have about the same proportionate development as in *A. lumbricoides*.

An arrangement of the excretory tubes similar to that just described also exists, in all

probability, in the genus *Spiroptera*, although the vessels are most likely minute and difficult of detection. I found this belief upon the following evidence. EBERTH has carefully examined three species of the genus, and makes no mention of the existence of ventral glands in either, though he has described and figured* a delicate axial vessel in the lateral band of *Spiroptera uncinata*. He discovered the lateral cervical pores in these animals, and as he looks upon them in the Nematoids generally as lateral openings of the vessels, taking the place of the single ventral pore, he probably never carefully searched for this. SCHNEIDER†, however, does state that the ventral opening exists in *Spiroptera obtusa*, and I have been led to a similar belief from what I have observed in the same animal. The specimens I examined had been preserved for a long time in spirit, and were in a rather poor condition, so that I was quite unable to detect any vessels in the lateral bands. Although I believe they exist, in all probability they are of small size‡. At all events I could not positively make them out, though I did detect a union of the lateral bands beneath the œsophagus (Plate XXVI. fig. 20) close behind the head. Thus a ventral opening was seen by SCHNEIDER, an internal arch by myself, and a contained axial vessel in another species of the same genus by EBERTH. *Spiroptera obtusa* is most remarkable for the great inequality in the size of its lateral bands; in the cervical region of the body they are almost equal on the two sides, but throughout the greater part of the extent of the animal the right is enormously developed (Plate XXVI. fig. 19), forming a great projection, which near its middle occupies nearly one-third of the general cavity of the body. A considerable quantity of fibrous tissue seems to enter into its composition, and both it and the small one of the opposite side seem bisected by an imperfect horizontal septum of this kind.

I have carefully examined many specimens of *Prosthecosacter inflexus*, and in none could I discover any trace of a ventral gland. At the anterior extremity, however, close behind the mouth, I detected a distinct funnel-shaped depression, this being the outer termination of a channel through the integument in the ventral region, at a level very slightly posterior to that of the capillary lateral pores (Plate XXVII. fig. 3). From the lateral bands, also, delicate processes were given off on each side, which met at the ventral aperture, but neither in these, nor in the lateral bands § themselves have I detected any actual vessel. If it exists, as the structures would seem to point out, it is probably very small.

I have now to describe some remarkable modifications in the arrangement of these vascular or excretory canals which are met with in the so-called *Filaria piscium*, and in two animals at present included in the genus *Ascaris*, viz. *A. osculata* and *A. spiculigera*. In

* Untersuch. über Nemat. Taf. ix. 6.

† MÜLLER's Archiv, 1858.

‡ I have since ascertained that SCHNEIDER does report the existence of such delicate vessels communicating with one another anteriorly (*Vide* EBERTH, Untersuch. über Nemat. p. 64).

§ It is very difficult to detect a delicate vessel in these bodies, either in their longitudinal direction, when the lateral bands are solid and opaque as in this animal, or even more so in transverse sections; a delicate-walled vessel becomes obliterated by the mere mechanical process of making the section.

Filaria piscium SIEBOLD* described "un organe rubaniforme caché dans la cavité du corps, parcouru par des canaux formant un réseau, et qui rappelle les lemnisques des Acanthocéphales." He also stated that he had met with a similar organ in *A. osculata.* SCHNEIDER confirms† SIEBOLD'S account of the existence of this organ in a species of *Filaria piscium*, and discovered that the main canal traversing it leaves this body to open externally. He is uncertain whether to look upon it as a special organ, or as a part of the ordinary water-vascular system, and states moreover that the lateral band of the left side appeared to be wanting in the animals he had examined. It must be borne in mind that under this same name of *Filaria piscium* several different species are probably included. I do not know from what animal the immature Nematoids examined by SIEBOLD and SCHNEIDER were taken. In all likelihood they were not from the Haddock, since in animals removed from beneath the peritoneal membrane of this fish I have found a different structure prevailing. In them, both lateral bands were present and of the same size (Plate XXII. figs. 6 & 8), though only the one of the left side possessed an axial canal. This canal could be seen most distinctly when the entire animal was examined. It was provided with distinct walls having an appearance of internal septa at intervals (Plate XXII. fig. 7), pursued an undulating course, terminating apparently near the extremity of the body in a cæcal ending, and left the lateral band anteriorly to open in the mid-ventral region opposite the termination of the anterior third of the œsophagus. Nothing corresponding to a lemniscus could be detected, and no vessel seemed to be given off from this main canal in any part of its extent. This arrangement is very interesting, inasmuch as it may be considered directly intermediate between what has been already described as existing in *A. lumbricoides*, &c., and what I have met with in *A. osculata* and *A. spiculigera*‡. In both these latter animals I have found a canal on the left side of the body only, which leaves the substance of the lateral band, far forwards, to gain the ventral region, where it appears to open at the anterior extremity of the body between the two lower head lobes. In both it gives off numerous branches in the substance of the left lateral band, and ramifies still more minutely in a peculiar, elongated development from this structure existing in the anterior part of the body (Plate XXVI. figs. 6 & 7). This prolongation constitutes the so-called "lemniscus" of SIEBOLD. The ramifications of the canal are confined to this lemniscus, and to the portion of the lateral band anterior to it; so that no vessels or canals can be found on either side in the lateral bands of the posterior half of the body. In both animals the lemnisci present a somewhat similar appearance; they are elongated structures lying by the side of the left lateral band, deeper in tint than it and of a light brownish hue, varying in different

* WIEGMANN, Archiv, 1838, i. p. 310. *Idem* in Man. d'Anat. Comp. 1850, vol. i. p. 135.

† MÜLLER'S Archiv, 1858.

‡ I was induced to examine this latter animal on account of a peculiar structure stated to exist in it by DUJARDIN, which he described in these words: "*Cloison* séparant l'intestin de l'uterus, et formée par un cordon jaune glanduleux épais, que des membranes blanches unissent aux deux cordons latéraux" (Hist. Nat. des Helminth. p. 206). The only body at all answering to this description is what I am now about to describe.

individuals in width and thickness, and also in length from $\frac{1}{2}''$ to $1''$. The lateral bands themselves in both these species have a kind of bilobed structure, and the lemniscus seems to be a growth from the anterior part of the ventral division of the band on the left side, which extends backwards in contact with it, and gradually terminates by a narrow posterior extremity. In transverse sections, though they are in close apposition, the demarcation can always be detected between this body and the left lateral band, as well as the existence of a tissue connecting it with the band of the opposite side. This tissue is composed of an intermixed mass of fibres and nucleated cells, similar to those existing in the deep integumental layer. This difference exists between the lemnisci in the two species: in *A. osculata* it seems to be hollowed out in the greater part of its extent into a flat elongated oval cavity, and the main canal runs along the free border of the organ (Plate XXVI. fig. 6) distributing branches on all sides; whilst in *A. spiculigera* only the rudiment of a central cavity exists near the middle of the organ in the form of a small somewhat fiddle-shaped cavity (Plate XXVI. figs. 14 & 16), and with the exception of a slight detour around this, the main channel runs along its centre, distributing branches freely as before. These branches* form at their extremities the finest possible network of interlacing canals (Plate XXVI. fig. 7). Whether or not they ever end in free extremities I was unable to determine; they all seemed to possess distinct though delicate walls, and no cilia could be detected within them. Their walls are probably contractile, and in the main canal I detected the remains of some granular contents. Posteriorly the central canal may be seen gradually to diminish in size, and terminate almost imperceptibly at the narrow extremity of the lemniscus itself (Plate XXVI. fig. 6).

I now come to the last principal modification of these canals as existing in the Nematoids. When SIEBOLD first called attention to these tubes, he stated that in *Ascaris dactyluris* and in *A. paucipara* two anterior branches, as well as two posterior, existed in connexion with the ventral aperture. SCHNEIDER† also represented a similar arrangement in *Pelodytes strongyloides*, *Dacnitis esuriens*, and *Leptodera flexilis*, whilst at an anterior period Professor HUXLEY‡ had more fully described a similar distribution of contractile canals in a Nematoid from the Plaice, which he spoke of as an *Oxyuris*. I have searched in the same fish and discovered in it an animal in all respects similar to that represented by HUXLEY. This animal, however, I feel almost certain is not an *Oxyuris*, but the *Dacnitis esuriens* § of DUJARDIN and SCHNEIDER. In all other respects I am able to confirm the statements concerning it made by HUXLEY. The ventral aperture is situated far back near the posterior extremity of the œsophagus; it seems to lead into a rather indistinct sacculated organ, which in its turn communicates (Plate XXVII. fig. 11), in a manner that I was unable precisely to make out, with the longitudinal canals close to the junction of the anterior and posterior branches. These canals are distinct walled tubes, which perforate and are situated in the lateral bands of the animal

* Best revealed by immersing the organ in strong acetic acid.

† MÜLLER's Archiv, 1858 and 1860.

‡ Med. Times, 1856, vol. ii. p. 384.

§ *Cucullanus heterochrous* of DIESING, Syst. Helminth. vol. ii. p. 241.

(Plate XXVII. fig. 13, *b*, *b*). Just posterior to the position of the contractile sac, by means of which they communicate with the exterior, they bend towards the ventral aspect of the body, and the acute angle which the anterior and posterior branches of the same side make with one another is merely due to a bend of the canal, as I have frequently seen their contents pass in an oscillating manner down one limb, through the bend, and up the other, in both directions. As described by HUXLEY, the posterior canals terminate cæcally close to the posterior extremity of the body (Plate XXVII. fig. 11), and I have in addition seen the anterior branches terminate in a similar manner opposite the middle of the pharyngeal cavity. No branches seem to be given off from these canals in any part of their extent; they are of a somewhat varying calibre, the anterior branches being rather broader than the posterior, and in both may be recognized a series of imperfect septa extending inwards from the walls of the canals. Their contents are a clear transparent fluid, in which a number of minute molecules are suspended; these seem to be driven backwards and forwards, partly by the movements of the animal, and partly by the contraction of the canal containing them. No cilia can be detected in their interior. This is the only Nematoid in which I have actually seen contractions of the lateral canals. The lateral bands containing them are of much the same structure as others I have already described, only they often contain a series of nuclei, and what appear to be clear spaces*.

We have thus seen that the structure of the lateral bands is by no means always the same, and that longitudinal vessels do not exist within them in all cases; and, I must say, I think it highly desirable that the descriptions of these structures as they are met with in some species of the genera *Heterakis*, *Oxyuris*, and *Strongylus*, given by EBERTH† and WALTER‡, should be confirmed. In *Heterakis vesicularis*, EBERTH described the lateral band as containing a delicate central vessel; but if such a vessel really exists it must form part of an arrangement different from any that has yet been described. I have somewhat hastily examined individuals of the same species, and was quite unable to detect such longitudinal vessels by any external inspection. And on account of the small size of the animal I was unable to succeed, as EBERTH appears to have done, in making satisfactory transverse sections. EBERTH does not seem to have recognized the ventral opening and tube, which from its general appearance, and from the fact of similar structures existing in an allied§ animal (*Heterakis acuminata*), I believe to be the terminations of a single or double ventral gland. Certainly it is not likely to be

* The representation SCHNEIDER has given of the lateral bands in *Dacnitis esuriens* is I believe erroneous. It seems to me that he has been misled by the appearance of the indistinct intestinal cells lining the very broad portion of the alimentary canal in this situation. Their very light colour and almost entire freedom from granular contents, was quite suggestive of cellular bodies, such as SCHNEIDER has figured in the lateral bands themselves (*loc. cit.* Taf. xv. fig. 8).

† Untersuch. über Nemat. 1863, p. 63. Idem in Würzb. Naturwiss. Zeit. 1860, Erst. Bd. p. 41.

‡ VIRCHOW'S Archiv, 1860.

§ I am quite aware that the difference between these two species would warrant their being placed in different genera, but still their resemblances are such that the genera would be allied.

an outgoing tube from a vascular arch formed from lateral vessels as in *A. megalocephala*, since the tube is here more than twice as broad as the whole lateral band (Plate XXII. fig. 10, *a*, *b*). I am sorry I had neither time nor specimens sufficient to examine this animal more fully. WALTER has described the lateral bands of *Oxyuris vermicularis* as closely resembling those of *Ascaris lumbricoides*, and like them containing an axial vessel; but then WALTER differs in so very many points from other observers, not only as regards the actual presence or absence of certain structures, but also as regards the interpretation of others well known and recognized to exist, that it would be desirable to have this observation verified by some other investigator. SCHNEIDER has been quite unable to discover the usual anterior ventral pore in this animal, neither have I, after the most careful search, been able to find it; and, notwithstanding the transparency of the animal, I certainly never could discover any trace of an axial vessel contained in the lateral bands. In *Oxyuris spirotheca*, moreover, SCHNEIDER has equally failed to discover a vessel within the lateral band; according to him it is made up solely of the usual admixture of granules and cells. The lateral bands of three species of the genus *Strongylus* have been described by EBERTH. In *S. tenuis* and *S. commutatus* he says may be seen the simplest condition of the lateral lines; in the former they consist each of a simple row of small cells, such as may be seen in many of the *Trichosomata*; in *S. commutatus* also the lateral lines are narrow and made up of small cells, whilst in this animal EBERTH also reports the presence of a double ventral gland. He states, however, that a different structure is met with in *S. striatus*, the lateral band being well developed, containing granular matter and nuclei, and also a delicate axial vessel; but in this species he does not seem to have certainly detected a ventral gland; he speaks of two organs, indeed, within the cavity of the body, though he also states that these seemed to be prolongations from the œsophagus, and that he was unable to recognize any external orifice. The organization of this animal must therefore be considered as still doubtful.

EBERTH seems to have examined the *Trichocephali* and *Trichosomata* much more fully than any other observer, and he makes no mention of the existence in them either of any modification of the ventral gland, or of vessels contained within the lateral bands. The structure of the longitudinal bands, both lateral and median, is of two principal kinds in these animals; and although they present the greatest variety as regards arrangement and relative size in different species, their actual histological structure is almost uniform throughout the whole group. He describes the simplest form as consisting of a long string of small cells or nuclei, which may either form a single row occupying the whole breadth of the band, or when the band is larger lie in contiguous rows, the several cells of which are separated from one another by a finely granular material*. The size of the single cells is variable; and whilst the smaller ones contain only a minute punctiform nucleus, the larger are beautiful polygonal bodies,

* In connexion with this structure of the lateral band it will be well to notice also what EBERTH says of the so-called granular layers in these animals. His words are, "Dicht unter der Haut trifft man eine zarte feinkörnige Schicht, die mir aus sehr zarten Zellen zu bestehen scheint."—Unters. über Nemat. p. 46.

with a well-marked nucleus and granular contents. The other modifications of the longitudinal bands met with in these animals are those concerning which I had to speak in the section on the tegumentary organs, as being connected with such an enormous number of integumental pores. On this point, however, my views are, as before stated, at variance with those held by EBERTH. As pointed out by this observer, the bands in connexion with these integumental pores frequently disappear in the posterior parts of the body, whilst the others usually extend along the entire length of the animal. In the *Trichocephali* but one such band seems to exist in the dorsal part of the anterior thread-like portion of the body, whilst in the genus *Trichosoma* the greatest variety prevails*. Thus in *T. resectum* and *T. plica* two equal bands of this kind exist in the lateral region of the body; in *T. spirale* there is a broad dorsal and a narrow ventral band, and in *T. aërophyllum* just the opposite arrangement; whilst in *T. dispar* two broad lateral bands as well as a narrow dorsal one are met with. In many of the *Trichosomata* (in accordance with what I have myself seen in *T. longicolle*) EBERTH represents what I believe to be the integumental pores, situated over bands composed of ordinary cells. He, however, describes the structure existing in the dorsal region of the *Trichocephali* as being composed of an aggregation of columnar, polygonal cells†, and this accords pretty closely with what little I have been able to ascertain concerning its structure. I distinctly recognized that it presented a kind of loculated appearance in some thin transverse sections which I succeeded in making of the anterior extremity of *T. affinis*, though I was unable to make out its exact structure and relation to the integumental channels immediately external to it. I think it quite possible that this band, as well as the other forms of the longitudinal lines met with in the Nematoids, may be a development—only a more specialized one—of the deep cellular layer of the integument. With regard to the existence of secondary median lines in these animals, and many interesting details concerning the remarkable variations in the proportionate size of the longitudinal bands generally, EBERTH'S valuable Monograph should be consulted.

It has been already stated that in *Strongylus tenuis* and *S. commutatus* a simple cellular condition of the lateral lines may be seen, such as is so common in the group concerning which we have just been speaking, and, according to the observations of both EBERTH and myself, this is the condition of things most commonly met with amongst the free Nematoids. In many forms which EBERTH has well represented, the simple cellular structure is most distinct. It may be seen amongst the species of the genera *Enoplus*, *Oncholaimus*, *Leptosomatum*, *Dorylaimus* and many others, whilst in some the individual cells cannot be made out, and a simply granular band appears to exist (Plate XXVIII. figs. 34 & 35). In many genera, moreover, amongst which I may mention *Rhabditis*, *Tylenchus*, and *Plectus*, I have failed to recognize any trace of a lateral band.

* *Vide* EBERTH'S Unters. über Nemat. Taf. vii.

† He represents the muscular layer as covering the whole inner surface of this body in *Trichocephalus dispar*: concerning this animal I can say nothing, though I am quite positive that such is not the case in *T. affinis*—here the cellular band is still an intermuscular organ.

Nothing that can be called a lateral band is met with in *Dracunculus medinensis.* In this animal, it is true, an unusually wide intermuscular space exists (Plate XXV. fig. 14), covered by a thin stratum of the deep cellular integumental layer; and though no prominence whatever can be observed, we must undoubtedly look upon this portion of the granulo-cellular layer lining the chitinous external integument, as the undeveloped homologue of what, in most Nematoids, constitutes the lateral band. We see in this stratum, thin as it is, the characteristic nucleated cells*, and running along its median line a most delicate vessel only $\frac{1}{6000}''$ in diameter. What is the nature of the peculiar ganglionated cord (in the same position and in contact with the longitudinal vessel) which I formerly described as a nerve, I am now quite unable to understand†. I have been able to ascertain nothing concerning it by means of transverse sections, except that it seems to constitute a flat band whose situation is not even marked by a thickening of the cellular layer in the middle of the intermuscular space. The anterior and posterior terminations of these bodies, as well as of the longitudinal vessels, is still unknown, and must be made the subject of future investigation.

The *median lines* have been frequently mentioned incidentally, so that I have now little to add concerning them. As before stated, they do not always exist, but when present I believe their method of formation and structure to be similar to that of the lateral lines. I therefore look upon them also as developments of the deep layer of the integument. They are usually small and narrow, in accordance with the nature of the intermuscular interval in the mid-dorsal and mid-ventral regions; but, as we have already seen in certain species of the genus *Trichosoma*, the dorsal or ventral bands may much exceed the lateral in width, and a study of these animals alone is sufficient to support the opinion of the absolute identity, as regards histological structure, of the lateral and median bands in the Nematoids—an opinion, however, which I had held long before I was aware of the additional proof afforded by the interchangeable nature of these structures amongst the *Trichosomata.* Accessory median lines, one on each side of the primary, exist in many of these animals, and the same arrangement appears to prevail in *Prosthecosacter inflexus* (Plate XXVII. fig. 4, *b'*, *b'*). In this animal they form the narrowest possible prolongations up between the muscular bundles, and are principally recognizable when the body of the animal is slit open and the internal organs removed, by the slight swellings which appear in their course, at intervals, along the surface of the longitudinal muscles. The ordinary single median line in the dorsal and ventral region may be best studied in *Ascaris lumbricoides* and *A. megalocephala*, and in *Spiroptera obtusa.* They seem to me absent altogether in *A. osculata*, *Cucullanus heterochrous*, and a species of *Filaria* which I have examined, whilst EBERTH has also failed to recognize them in *Strongylus tenuis* and *Sclerostomum dentatum.* They very likely exist in

* *Vide* Trans. of Linn. Soc. vol. xxiv. pl. 21. fig. 25.

† When I formerly made this statement I did not know so much concerning Nematoid Anatomy, and although I never felt quite satisfied about its histological resemblance to a real ganglionated nervous cord, I at the time described it as such simply by way of exclusion—there seemed to be nothing else which it could possibly be.

some species of free Nematoids, although their minute size has hitherto prevented their detection.

Eberth still believes that the median lines in some Nematoids constitute a part of the water-vascular system, whilst Walter goes much further, and states that they anastomose with the lateral vessels, and also send off a number of transverse branches on either side. These transverse branches are what Walter formerly described as peripheral nerves, but which have now been most conclusively shown by Schneider and myself to be merely transverse prolongations from the muscle-cells to the median lines. Schneider does not look upon the median lines as belonging in any way to the vascular system. I have no doubt concerning the general structure of the median lines; and the description given of them in several species, both by Walter and Eberth, to the effect that they are composed of a delicate membrane enclosing a number of highly refracting particles, is not only in accordance with my own observations, but also in harmony with the belief that they are developments of the deep integumental layer. As I stated, however, in my paper upon the Guineaworm, these structures in this animal have a somewhat different formation, not presenting the granules and being of a more fibrous nature; and after the most careful investigation of them, I came to the conclusion that they were hollow, and in fact constituted vessels of some kind. At the same time I stated that I had frequently been almost led to believe that a lacunar channel did exist in the median lines of *Ascaris lumbricoides*. The difficulties besetting the investigation of these structures is extreme, and I am still somewhat undetermined upon this point. I have fancied from time to time that a lacunar channel existed in these bodies both in *A. lumbricoides* and *A. megalocephala*, but can say nothing positive upon the subject. The existence of peculiar transverse vessels to be presently described in the deep integumental layer of both these animals, also seems to lend support to this idea. Dr. Schneider's views concerning the structure of the median lines in the *Ascarides* have already been alluded to when speaking of the nervous system.

A statement has now been made of almost all that is at present known, not only concerning the nature of the structures in connexion with the anterior ventral aperture of the Nematoids, but also concerning the formation of the lateral and median bands. And at present the balance of evidence is decidedly in favour of the view I have adopted, that the so-called ventral glands met with in some Nematoids, and the axial tubes seen in the *Ascarides*, *Cucullanus*, and other animals—organs communicating with the exterior by a median pore—are all only modifications of one and the same structure. From the abortive saccule of *Oxyuris ambigua*, we see the organ progressively developing into a simple tube in some of the free Nematoids, a tube with a dilated nucleated extremity in others, and in the *Strongyli*, *Sclerostomata*, and others, we get a bifurcation of the organ, which still opens, however, by the same median pore. In *Ascaris megalocephala*, *A. lumbricoides*, &c., the outgoing tube and the arch are still situated, like the ventral glands, in the general cavity of the body, so that up to a certain stage of development we may imagine the structure of one of these animals, so far as this organ is concerned.

closely to resemble that of a *Strongylus*; but at a more advanced stage a specialization occurs, the extremities of the gland no longer proceed with their development in the general cavity of the body, but each tending towards that of its own side, perforates the lateral band and continues to extend lengthways in its substance in the form of a uniform tube or vessel. In the *Ascarides* the ventral aperture is situated far forwards towards the head, whilst in other Nematoids, such as *Cucullanus heterochrous**, it is found situated much more posteriorly, opposite the termination of the œsophagus; and here, accordingly, in addition to the two posterior branches which perforate the lateral bands as in *A. lumbricoides*, a still further specialization exists, and two anterior branches are given off to occupy those portions of the bands in front of the median aperture.

In that form of the so-called *Filaria piscium* which I examined, may be seen the rudimentary condition of a more complex arrangement existing in *Ascaris osculata* and *A. spiculigera*. Here a single tube in communication with the ventral pore leaves the cavity of the body to perforate the left lateral band, in the axis of which it exists as a simple unbranched vessel, whilst in *A. osculata* and *A. spiculigera* a corresponding tube, also on the left side, sends off an infinity of inosculating branches which ramify in the substance of the lateral band, and of a special development from it. The tubes in some of these animals have positively been ascertained to be contractile in their nature, and they seem generally to contain a clear colourless fluid with a variable number of small molecules suspended in it. In *A. lumbricoides* the contained fluid is frequently of a reddish colour. Although the body of the ventral glands is generally quite filled with granular matter, still in the terminal portions of their duct I have frequently seen amongst the free Nematoids a clear fluid with suspended molecules. I have especially noticed this in *Symplocostoma longicolle*.

I am fully impressed with the homological identity of these modifications of an excretory organ, as met with in the Nematoids, with that system of vessels in the *Trematoda* and other animals, which, from its invariable communication with the exterior, has been termed a "water-vascular" apparatus. As I shall have again to allude to this subject when treating of the affinities of the Nematoids, I will now merely call attention to the following facts:—that in both Nematoids and Trematodes the nature of the contents in this system of canals is the same, whilst in *Distomum tereticolle*†, as in *A. lumbricoides*, the fluid has been seen of an exceptionally reddish colour; that in some species of Trematodes, such as *Monostomum faba*, *Distomum cirrigerum*, and *Gasterostomum fimbriatum*, there exists in connexion with the external aperture only a simple sac; in others, such as *Distomum chilostomum*, *D. clavigerum*, *D. conjunctum*, *D. luna*, &c., as well as in several species of the genus *Monostomum*, it is a bifurcated organ; whilst in *Amphistomum conicum*‡ four main branches exist, although each of these sends off an infinity of offshoots.

I have still to speak of two varieties of vessels met with in the Nematoids, which

* *Dacnitis esuriens* of DUJARDIN.

† SIEBOLD's Man. d'Anat. Comp. p. 137, note.

‡ COBBOLD's 'Entozoa,' plate 3.

apparently have an independent origin, and no connexion with the system of tubes communicating with the ventral pore. The first variety is met with amongst the various species of four land and freshwater genera, all of which possess certain common characters, and amongst others an extraordinary tenacity of life and power of resuming their vital manifestations after the most prolonged periods of desiccation. These four genera are *Tylenchus*, *Plectus*, *Aphelenchus*, and *Cephalobus*. I have examined the vessels themselves most fully in adult specimens of *Tylenchus tritici**. In this species they are single, unbranched vessels, about $\frac{1}{3330}''$ in diameter, with thin transparent parietes and colourless contents, each pursuing an undulating and in some places an almost convoluted course along either side of the body. They are, certainly, throughout the greater part of their extent, unattached to the parietes of the body, but how they end either anteriorly or posteriorly I have been quite unable to ascertain. I have succeeded in tracing them to within a very short distance of each extremity of the animal, but never could detect either any external aperture with which they communicated, or union of the vessels of opposite sides. From the freedom, however, with which I have seen these vessels extruded with other contents of the general cavity, through ruptures of the posterior part of the animal by pressure of the covering glass, I am inclined to think that, posteriorly at least, they are unattached to the parietes of the body. When whole coils of these vessels were thus brought fairly into view, I never saw the slightest evidence of contraction in any part of their extent, neither could I detect any cilia in their interior; they seemed to contain a clear fluid devoid even of suspended molecules. In the other genera named I have never seen any approach to a convoluted arrangement of these lateral vessels, and they seem to pursue nearly a straight course. In the genus *Plectus*, however, each seems to start from, and to be connected anteriorly by a short narrower portion, with a circular marking (perhaps having a minute orifice in its centre) of the integument (Plate XXVIII. fig. 14). This is all I have been able to ascertain concerning these structures, and it is from what I have seen in *Tylenchus tritici* only, that I have been led to infer as a probability that the similar vessels met with in the other genera, occupy the same position in the general cavity of the body as I have proved them to do in this species. These four genera are further allied to one another by the fact that they alone of the land and freshwater Nematoids yet discovered possess any modification of the ventral gland before described, and that it exhibits essentially the same formation in all the species of these four genera, whilst this formation differs somewhat from the common type.

The other vessels in the Nematoids were, I believe, structures first noticed by SCHNEIDER† in *Ascaris lumbricoides*, though neither at that time nor at the present‡ does he take this view of their nature. He is somewhat perplexed by them, but upon the whole regards them rather as nerves than vessels. LEYDIG has also examined these structures, and believes them to be vessels—an opinion which I had, moreover, formed of them at a time when I was quite in ignorance of LEYDIG'S views upon the subject.

* Olim, *Vibrio tritici*. † MÜLLER'S Archiv, 1860, S. 240. Taf. vi. 10 u. 11. ‡ *Ibid.* 1863.

These vessels (assuming them to be such) exist in the substance of the deep cellular layer of the integument mostly in pairs, and extend from median line to median line. They cannot be examined without careful preparation of the animal, of such a kind* as to permit of the longitudinal muscles being entirely stripped from the surface of the granulo-cellular layer after its body has been slit open in a longitudinal direction. The best species for their examination is *A. megalocephala*, owing to the greater size of the vessels and to the readiness with which, in their passage from median line to median line, they may be traced through the substance of the lateral band. I have mapped out inch by inch, as correctly as possible, the entire series of these vessels as I found them existing in a specimen of *A. megalocephala* (Plate XXV. fig. 10), and having examined two other individuals in the same way, I found that they were distributed in the same unsymmetrical manner—more than twice as many vessels existing on the right side of the body as are to be met with on the left. And although I have not mapped out the entire series in *A. lumbricoides*, I have ascertained that in this animal a similar disproportion exists in the number of vessels found on the two sides of the body. I do not think the number or relative positions of the several vessels is absolutely similar in any two individuals of either of these species: small differences exist in different individuals, through a general similarity of arangement prevails. The general course of the vessels may be best seen with a low power of the microscope, when they have the appearance of bright undulating channels distinguishable by the total absence of granules in their course through the dark granular membrane. Magnified to this extent they seem mere lacunar passages only. They may generally be seen running in pairs; starting, for instance, from the dorsal median line at a short distance from one another, we may see them pursuing an undulating course, either parallel with one another or not, till we come to the lateral band, through which they may be seen to pass, generally external to the longitudinal vessel, and apparently unconnected with it in any way, and then through the remaining tract of granular material till they reach the ventral median line, where they may be either closer to one another or further apart than they were at the dorsal line. As may be seen by the figure, during this course the two vessels may cross one another either once, twice, or not at all; they may keep at a pretty uniform distance from one another, or may diverge widely. Where the vessels cross only once, this most frequently occurs during their passage through the lateral band, and in some cases they run so obliquely through this as to appear on the other side at quite a different level from that at which they entered (Plate XXIII. fig. 7, and Plate XXV. fig. 11). More rarely a single vessel may be seen pursuing this same course between ventral and dorsal lines, and, rarer still, a single vessel stretches from one of the median lines to the lateral band only, and there ends. These vessels have an almost uniform calibre throughout their extent, at all events no dilatations may be seen in their course

* This may be most readily effected by maceration for about a week or ten days in dilute nitric acid. The muscles require to be removed with great care, in order not to injure the layer in which the vessels are contained.

or at their terminations; their breadth varies, however, from $\frac{1}{1000}''$ to $\frac{1}{500}''$ in *A. megalocephala.* When examined with a power of about 200 diameters, it can be seen that the granules between which the vessel lies are displaced by an intervening body, and that there is something more than a mere lacunar canal. It may frequently be seen that one of the vessels composing the pair, in the neighbourhood sometimes of the dorsal, and sometimes of the ventral median line, is more irregular and undulating in its course than usual, and from this portion short branches appear occasionally to arise which extend into the neighbouring granular material. This was also observed and figured by SCHNEIDER. Sometimes, moreover, a slender transverse branch may be seen uniting the two vessels in the same situation; but with these exceptions the vessels appear to be quite unbranched. All attempts to follow them into the substance of the median lines have utterly failed, and after the most careful examination I have also equally failed to discover any channels through the integument opposite their terminations; and I have so repeatedly searched for these in vain, that I can almost confidently assert they do not exist. When portions of the vessels are isolated from the layer in which they are imbedded they appear as flat bands, whitish in colour, and as if composed of longitudinal fibres with minute interspersed molecules, though it is extremely difficult to convince oneself in this way that they are in reality hollow tubes. They have much the appearance of flat solid bands, such as SCHNEIDER believes them to be. But I am almost convinced this cannot be the case, since several times, on examining a portion of the animal in which I had been endeavouring to isolate these bodies, I have found the vessels torn across in some part of their course, whilst the remaining portion still lying in an undisturbed part of the cellulo-granular layer, now no longer occupied the whole breadth of the lacunar channel in this structure—as they all invariably do before they have been disturbed—but was so diminished in size as to occupy no more than one-third of this space. Is it likely that the traction exercised in the act of tearing this structure across would, if it were a solid band, cause it to shrink to this extent? I think not; though this might very easily occur with a thin-walled vessel, such as I believe this structure to be. If they really are solid fibrous bands, what can they be except either muscles or nerves? But putting aside the *primâ facie* improbability of such an extraordinary and unsymmetrical arrangement of muscular bands, such a view as to their nature seems absolutely negatived by the fact of their undulating course, and their situation in the midst of a structure which would be disturbed and destroyed by their action. Then, again, with regard to the other view, which seems to find most favour with SCHNEIDER*, that these bands belong to the nervous system, we are met by the fact that, according to my measurements, they are often three times as broad as the largest nerve-fibre I could find issuing from a ganglion-cell in connexion with the œsophageal ring. In addition to this there is the difficulty of their asymmetrical distribution, which seems quite inexplicable on the supposition of their being nerves, though it can be smoothed over to a certain extent if we regard these structures as transverse vessels simply destined to bring the dorsal and ventral median lines into

* MÜLLER's Archiv, 1863, S. 10.

contact with one another. If this were their principal office, we can imagine that it might be, to a certain extent, immaterial whether the connecting vessels traversed the left or the right half of the body, or were distributed unequally on the two sides. Then comes the puzzling question, what can be the use of vessels to establish a communication between what appear to be two solid cords? And in reply I can only again refer to the impression which I have frequently been inclined to adopt, that in some species the median lines are traversed by a lacunar canal, and at the same time deplore the difficulties besetting the solution of this question. SCHNEIDER states that these vessels have a reddish colour in *A. megalocephala*; this I suppose must have been seen in the fresh animals before immersion in spirits of wine, in which condition, owing to their poisonous effects upon me, I have never been able to examine them. The colour was in all probability due to the fluid contained within the vessels. I have looked for similar transverse vessels in many Nematoids, but have only found them in the two above named. SCHNEIDER, however, states that he has discovered them in *Heterakis vesicularis*, and many other minute Nematoids, though he has failed to recognize them in any species of the genera *Oxyuris* or *Strongylus*. Further investigation, both with regard to the connexions of these vessels, and to their prevalence amongst the Nematoids generally, would be most desirable.

THE RESPIRATORY FUNCTION—HOW PERFORMED?

Amongst the lower Invertebrata it is a well-known fact that the function of respiration is effected by the most dissimilar means, and often by distinct processes working independently in the same animal towards the fulfilment of a similar end. We need not be surprised therefore if such is found to be the case amongst the Nematoids. It is, however, rather remarkable that cilia, which often (as first pointed out by Dr. SHARPEY *) play so important a part in the respiratory processes of the invertebrate animals, should never yet have been detected in any Nematoid either parasitic or free.

The function of respiration seems to be duplicate in its nature: one object which it fulfils in the animal economy being to secure a certain amount of oxidation of the tissues, and the other being the performance of a function of elimination, supplemental in its nature to the similar work effected by the two other great excretory organs, the kidneys and liver †. It may well be that the relative proportions of these two processes in different animals may be variable, since a greater activity of the eliminatory function —performed by organs howsoever named—might atone for an inefficient accomplishment of the process of oxidation. In many of the parasitic Nematoids, we can well

* Cycl. of Anat. and Phys. vol. i. Art. *Cilia.*

† Even this process of oxidation appears to be in great part destined to perform a disintegrating function, and so may perhaps be looked upon as the first stage of a process of elimination. Dr. LIONEL BEALE says, "Oxidation seems to be connected rather with the disintegration or removal of *fully developed and worn-out tissue* than with the growth and multiplication of masses of germinal matter."—*On Inflammation,* Med. Times, 1865, vol. i. p. 594.

imagine, from the situations in which they are found, that the very existence of organs destined to facilitate such a process of oxidation would only be productive of evil rather than good. And the facts revealed by the anatomy of these animals tend to support this *à priori* assumption. We meet with glandular structures and excretory organs in abundance, but with no trace of a special apparatus destined to secure an aëration of the tissues; such a function is, I believe, almost in abeyance in the parasitic Nematoids, whilst the glandular and eliminatory function is more than ordinarily developed.

It seems absurd to imagine that the two longitudinal tubes, in connexion with the ventral pore in certain species of the genus *Ascaris*, could be destined to admit external fluids for the purpose of respiration. And even if all evidence were not opposed to this suggestion, a consideration of the more rudimentary condition of this apparatus, as met with in the genus *Strongylus* and so many other Nematoids, would of itself go far towards its refutation. Here we have undoubtedly to deal with an excretory glandular apparatus. No one could for a moment regard these structures as at all analogous to vessels destined alternately to receive and discharge an external fluid medium. I believe that in the *Trematoda* and *Tæniada* also, where similar, though often more developed systems exist, their function is in like manner one of a purely eliminatory kind, and I cannot therefore but look upon the name of "water-vascular" apparatus as a singularly inappropriate appellation for this system of vessels.

In those Nematoids in which this excretory system is most developed, where the vessels or tubes composing it are lodged in the lateral bands or developments from them, it may be, perhaps, that these cellular structures bear the relation to them of parenchyma to gland-ducts. It may be noticed also, that in the *Strongyli*, *Oxyurides*, and many free Nematoids in which this excretory apparatus exists in the more undeveloped condition of a ventral gland, its eliminatory function appears to be supplemented by the presence of almost similar glandular structures in connexion with the anus and vagina.

With regard to the integumental pores, they seem also to countenance the belief that the deep integumental layer is to a certain extent an excretory organ, and I am inclined to look upon them as a series of excretory channels in connexion with this structure, having a sort of distant analogy therefore with sudorific ducts. That such is their nature is to a certain extent countenanced by the fact of their extreme abundance in the *Trichocephali* and *Trichosomata*, in which no ventral gland or other modification of this excretory apparatus is to be met with; so that the function of these seems to be performed by the cellular bands and related integumental pores so universally met with in the animals of this group. Amongst the free Nematoids, too, the very species in which these integumental channels are met with in the most marked abundance, such as *Dorylaimus stagnalis* and *Leptosomatum figuratum*, are also those in which there is to be found no trace either of ventral, anal, or vaginal glands.

Amongst the free Nematoids we might expect to meet with some evidence of the performance of the aërating portion of the respiratory process, and I think this may be

effected in part by means of the fluid so constantly observed in the alimentary canal of these animals, which is kept in almost perpetual movement by the rapid undulations of their bodies. As first observed by CARTER in his *Urolabes palustris**, and since witnessed by myself in *Dorylaimus stagnalis*, there seems to be a more special provision for a respiratory process of this nature amongst the *Dorylaimi*, somewhat similar to what occurs amongst the *Naïdinæ*. The posterior portion of the intestine presents a modified structure in these species, which in all probability has something to do with the process alluded to; in *Dorylaimus stagnalis*, for instance, for a distance of $\frac{1}{50}''$ of an inch it is almost devoid of the thick lining of hepatic cells met with throughout the rest of its extent (Plate XXVIII. fig. 4, *a*). In individuals of this species I have seen sudden jets of clear fluid expelled, by contraction of the intestine, through the anal cleft, in a periodical manner, at intervals of four or five minutes. After its expulsion the anal cleft seems to close immediately with valve-like rapidity, and how the fluid enters for the next discharge is rather obscure. In the *Naïdinæ* the process is perfectly simple; the fluid is introduced through the anal aperture by the agency of powerful cilia lining the whole posterior portion of the intestine, and is as distinctly expelled by intestinal contraction. The most careful search, however, has revealed no trace of the presence of cilia in the *Dorylaimi*. It is true, they may be so small as to have escaped recognition.

In the genera *Tylenchus*, *Plectus*, *Aphelenchus*, and *Cephalobus*, the ventral gland is in a somewhat rudimentary condition, and the integumental pores seem wanting altogether; it therefore seems possible that the superadded lateral vessels met with in these animals may in some way be connected with the function of respiration†.

ORGANS OF GENERATION.

I have comparatively little to say on this subject. There is no particular discrepancy in the accounts given of these structures by different observers; their general form and arrangement is pretty well known, and nothing more was likely to be learned from them which would be of material assistance in determining the affinities of the Nematoids. I have therefore not made these organs the subject of any systematic investigation, and in addition to pointing out their prevailing form in the free Nematoids, have only a few scattered facts to mention under this head.

In the "Monograph on the Anguillulidæ," I called particular attention to the fact of the great uniformity in the disposition of these organs amongst the free Nematoids, and stated that for this amongst other reasons it seemed to me desirable to locate them in a family altogether distinct from those into which the parasitic species are divided, since in only two or three exceptional parasitic species is the same arrangement met with.

The form and position of these organs‡, in both the male and female *Dorylaimus stagnalis*, I have represented in Plate XXVIII. figs. 1 & 2, and this may be considered as

* Really *Dorylaimus palustris*. *Vide* Ann. of Nat. Hist. Ser. 3, vol. iv. p. 33, pl. 2, fig. 7.

† *Vide* note, p. 619.

‡ For the sake of clearness they have been drawn in a somewhat diagrammatic manner.

their typical condition in the *Anguillulidæ*. We find in the female a transverse vulva opening near the middle of the body in the ventral region, with a short vagina leading into a symmetrical, double uterus whose cornua extend on either side; these uteri are separated by constricted portions from narrower oviducts, whilst these in turn communicate with reflexed ovarian tubes. The oviduct has scarcely ever a greater proportional length than is represented in the figure, and is often proportionally much wider, as may be seen in the members of the genus *Plectus* (Plate XXVIII. fig. 15). We never meet with the long filiform ovaries so characteristic of many of the parasitic Nematoids. In a certain number of the *Anguillulidæ*, however, the vulva is situated near the commencement of the posterior third of the body, as in the genera *Monhystera*, *Tylenchus*, &c., and in these cases the posterior uterine segment remains undeveloped, whilst the anterior half which does exist preserves the characters above described. In the male there are two somewhat elongated ovoid sacs or testicles, connected by narrow canals with the commencement of a simple tube or vas deferens, which opens externally, together with the intestine, at the anal cleft. On either side of its termination, and capable of being protruded through the anal cleft, are two spicules, equal in size and of a horny nature. These spicules may be either solitary, or provided with one, two, or even four accessory pieces. In two species, *Monhystera ambigua* and *M. disjuncta*, I have seen the genital tube opening separately from, and anterior to the anus. In the former I was also unable to detect spicules of any kind, whilst in the latter, curiously enough, they were in their usual situation, and therefore quite separate from the termination of the genital duct*. In certain genera, such as *Rhabditis* and *Monhystera*, the male genital tube appears to be connected with only one testicle, which is separated by a constriction from the efferent duct†.

The spicules amongst the free Nematoids are not enclosed in a distinct sheath, such as we find amongst the *Ascarides* and many other parasitic Nematoids. In the genus *Ascaris* two equal spicules, each enclosed in a firm thick-walled sheath, are generally met with, one on each side of the body (Plate XXV. fig. 7 *n*, *o*), but in *Ascaris lumbricoides* I have found them very unequal in size and situated close to one another (Plate XXIII. fig. 4).

The structure of the genital organs met with in the Guineaworm is, so far as I have seen, quite unique amongst the Nematoids, though it seems more easy to connect it with an extreme modification of organs such as are met with amongst the free Nematoids, than with anything similar amongst others of the parasitic species. The histological differentiation of its tissues, and the developement in it of well-marked elastic tissue, similar to what is met with in the vascular system of higher animals, is an interesting fact‡.

The spermatozoa in the parasitic Nematoids, so far as we know at present, are generally

* See, for this and various modifications in the form of spicules, "Monograph on Anguillulidæ," Trans. of Linn. Soc. pls. 9–13.

† Well represented by Davaine in Recherches sur l'Anguillule du blé niellé, pl. 3. fig. 1.

‡ Trans. of Linn. Soc. vol. xxiv. p. 118, pl. 22, figs. 34 & 37.

motionless, spherical, or ovoidal bodies of a cellular nature, and as such they also exist most frequently in the free species. Thus they are very small vesicular bodies in *Theristus acer* (Plate XXVIII. fig. 22), larger in *Comesoma vulgaris* (Plate XXVIII. fig. 23), much larger ovoid bodies of the same kind in *Monhystera ambigua*, $\frac{1}{625}''$ in diameter (Plate XXVIII. fig. 24), and small pyriform corpuscles in *Enoplus communis* (Plate XXVIII. fig. 25).

In *Rhabditis marina* I have seen the spermatozoa presenting totally different characters; they appeared as short cylindrical bodies $\frac{1}{5000}''$ long (Plate XXVIII. fig. 13), having moreover a slowly oscillating movement, which was seen to continue for more than twenty-four hours. In *Monhystera disjuncta* the spermatozoa were linear bodies $\frac{1}{1000}''$ in length (Plate XXVIII. fig. 26), having a slowly serpentine movement. The spermatozoa of *Dorylaimus stagnalis* are most frequently met with as bright highly refractive bodies, enclosed within a hyaline vesicle, though a later stage of evolution seems to convert them into free filamentous bodies $\frac{1}{1000}''$ long, and narrower at the extremities than in the middle (Plate XXVIII. figs. 8 & 9). It seems probable that the spermatozoa of different species are not always in the same stage of development when emitted from the male; in some cases they appear to continue their development within the female organs of generation, before coming into contact with the ova.

The only Nematoids I have seen in *actu coitus* were specimens of *Cephalobus persegnis*; the male was coiled around, at right angles to the female, in the same fashion as was observed by Dugès with specimens of *Anguillula aceti*, and as others have noticed in certain of the parasitic species.

There seems to be no fixed period of the year which may more especially be considered as the breeding-season of these animals; in spring, summer, autumn, and mid-winter alike I have found amongst the free species females containing impregnated ova. In the majority of these animals, too, the ova are very large in proportion to the size of the body, and few in number—in both respects presenting a striking contrast to what is usually met with amongst the parasitic forms. The two divisions of this order agree, however, in the fact that, whilst the majority of the species are oviparous, the remainder are viviparous, bringing forth active young, presenting in a miniature form the external characters of the adult animals.

DEVELOPMENT.

Under this head I have nothing new to say concerning the early development of the ovarian cells and spermatozoa, or the actual process of fecundation in the Nematoids. This has been treated of most fully with reference to the parasitic species by Nelson, Bischoff, Leuckart, Meissner, and Allen Thompson, and as it occurs amongst the free Nematoids by Davaine and Carter; and for the results of their investigations I must refer to the various periodicals in which these observations were recorded. To have gone over this ground, and to have endeavoured to reconcile discrepancies at present existing in the accounts given by these various anatomists, would of itself have been an

investigation demanding the utmost care and patience; and although it constitutes a subject replete with interest, I have not had sufficient time at my disposal to undertake it.

All are agreed, however, as to the direct method of development, by which the entire fecundated yelk-mass, after undergoing the well-known process of segmentation, is converted into the form of the future animal, either without, or whilst still enclosed within the body of its parent. Further than this, however, almost nothing is known concerning the after stages of development in which, by the development and differentiation of its internal organs, it attains to the typical form of its species; and this may be accounted for in a measure by the fact that, with one recent exception only, the complete and entire life-history of no other parasitic Nematoid has been fully revealed*. A gap remains in the history of most between the period of their emergence from the egg, and the time when they are usually met with as sexually mature individuals within the bodies of their various hosts. Whether during this intervening period they are to be met with in other primary intermediate hosts, in a non-sexual condition, such as we are familiar with in *Trichina spiralis* and the species included under the name of *Filaria piscium*, or whether during the course of their existence they are, as a rule, parasitic only within a single animal, is a question which at present we are unable to answer; and unfortunately the latest and most distinguished writer upon helminthology in this country has made such opposing and contradictory statements† as to leave us entirely in the dark as to the real nature of his views on this question‡. It is, however, amatter of perfect certainty as

* Since this was written Professor Leuckart has published an admirable paper "On the Developmental History of the Nematoid Worms" (Archiv für Wissensch. Heilkunde, Band II. pp. 195–235, and translated in the Annals and Magazine of Natural History, May and June, 1866), in which he has contributed very largely to our stock of knowledge on this subject. He has ascertained the complete life-history of many species of parasitic Nematoids, and gives numerous details concerning developmental modifications.

† Compare opinion expressed at p. 308 with that at p. 313 of Dr. Cobbold's 'Entozoa,' 1864.

‡ Professor Leuckart (*loc. cit.*) has now definitely ascertained that both these methods of development exist amongst the Nematoids. A synopsis of the different kinds of life-histories met with amongst these animals is given by him in the Bull. de l'Acad. Roy. des Sc. Belg., No. 3, 1866, p. 208. The most remarkable history yet revealed is that of *Ascaris nigrovenosa*. It has been shown by Leuckart and Mecznikow that the young of this animal, after passing from the rectum of the frog into damp earth or mud, grow rapidly, and actually develope in the course of a few days, whilst still in this external medium, into *sexually mature* animals. Young, differing somewhat in external characters from their parents, are soon produced, and these attain merely a certain stage of development whilst in the moist earth, arriving at sexual maturity only after they have become parasites, and are ensconced in the lung of the frog. Here, as Professor Leuckart remarks, we meet with "no simple alternation of the conditions of life, but with an alternate sequence of free and parasitic generations. And what is most wonderful, *both these generations are sexually developed*, both are produced from ova. Here, therefore, we have nothing to do with an ordinary alternation of generations, such as occurs, for example, in the *Distomeæ*, but with a process hitherto almost unheard of in the animal kingdom, and which calls for our consideration the more because we are accustomed to regard the sexual development of an animal not merely as the sign of its perfect maturity, but also as the criterion of specific individuality." The life-history of this animal will be more marvellous still if Professor Leuckart's supposition be correct (and it seems the most probable one) as to the young of the parasitic form being produced by a process of *agamogenesis*. No parasitic males of this species have ever yet been met with.

regards the free Nematoids that they undergo their development at once in the regions where they are born, in association with their parents, and other kindred species, young and old: generation succeeding generation in the same external habitat, and parasitism neither entering into nor being required by them in any stage of their simple life-history. In these therefore the whole process of development might be studied, provided the young animals could be kept alive and under observation during the period necessary for this investigation. I have not had much time to devote to this portion of the subject, and consequently have only a few rather unconnected details to bring forward, partly concerning the parasitic and partly concerning the free species.

In a former paper on the Guineaworm* I alluded to the various accounts that had been given concerning the anus and the termination of the intestine in the young contained within this animal. Amongst others I mentioned the description which CARTER had given of the intestine terminating "at the root of the tail," near what I have described as lateral saccules and he as a gland. I had seen another disposition of the intestine so plainly that I was inclined to believe CARTER must have been mistaken; and it did not occur to me that the discrepancy in our observations might be fully accounted for by the fact of our having examined young animals at different stages of their development. Now, however, I feel assured that this is the most probable explanation of the former discordance in our views, since in three or four Guineaworms of different sizes which I have since examined, I have found a difference in the degree of development presented by their contained young; and in one animal I found them in a more advanced stage than I had ever before seen, displaying the intestine communicating with the exterior by an anal orifice in the very situation indicated by CARTER—that is to say, slightly above the level of the lateral sacculi (Plate XXVII. fig. 22, *a*). Thus the young which I had before examined and figured, in which the intestine ended cæcally, were less mature individuals, and so exemplified what appears to be the usual course in the development of the intestinal canal in higher members of the animal kingdom. It exists first in the form of a cæcal tube which gradually elongates, so as to approximate and ultimately unite with an anal orifice commencing independently as an infolding of the parietes of the body. That the young I first examined were less mature is also indicated by the fact that the measurements I gave of them were below those given of the young *Dracunculi* by several other observers. In these last more developed animals in which I have been enabled to detect the anal orifice, I also recognized rudimentary conditions of the two head papillæ, and, more interesting still, discovered what has not yet been detected in the adult animal, in the form of a distinct channel through the integument in the ventral region of the body, about $\frac{1}{300}''$ from its anterior extremity (Plate XXVII. fig. 24, *a*). May not this be the commencement of one of the forms of the ventral excretory apparatus met with in the Nematoids? Whether, however, it is the outlet of a future rudimentary saccule, or of two longitudinal vessels which are to exist in the lateral regions of the body, cannot be said. In the adult *Dracunculus* I have now recognized

* Trans. of Linn. Soc. vol. xxiv. p. 122.

at a distance of $\frac{1}{285}''$ from the posterior extremity of the body two large caudal pores, apparently homologous with what are also seen to exist in the caudal regions of the *Ascarides* and so many other Nematoids (Plate XXVII. figs. 20, *c* & 21). And what I have described in the young of this animal as "lateral sacculi," I now suspect may be the early representatives of these lateral pores in the adult. The protrusions which are seen to exist in the place of these sacculi in some individuals are, I believe, due to a complete or partial extroversion of the walls of the sacculi. The proportionate size of these structures, as existing in the young, is certainly very large as compared with the pores in the adult; but if the sacculi are not to be considered their representatives, then we must look upon them as bodies altogether anomalous; whilst if they are so considered, we may expect to find the same structures more or less developed in the young of many other Nematoids. The differences in the relative position of anus, pores, and posterior extremity, as met with in young and old specimens of *Dracunculus*, is nothing more than might be expected, considering the enormous development attained by the adult, and the obviously wasted condition in it of the very elongated filiform posterior extremity existing in the young animal.

As I have stated elsewhere*, I am strongly inclined to believe that the Guineaworm was originally a free Nematoid, which, having obtained a direct entrance into the human body through the skin, attains an enormous size in the subcutaneous tissue. In the same place I pointed out, however, reasons why it could not, as CARTER imagined, be identical with his *Urolabes palustris*. The principal anatomical reasons lending support to the view of its being an enormously developed free Nematoid, are the following:—it has a very wide lateral intermuscular space, but no development whatever answering to the lateral band (Plate XXV. fig. 14, *f*), and, so far as we at present know, this is the case with no other parasitic species, though it is by no means uncommon amongst the free Nematoids for all traces of these structures to be absent†; the form of the young Guineaworms with their attenuated filiform extremities agrees closely enough with what is of most common occurrence amongst the free species, whilst if it exists at all amongst the parasitic forms, it must be a matter of the greatest rarity, since the only recorded instance of any approach to such a length and tenuity of the body posterior to the anus that I am aware of is in *Passalurus ambiguus*‡; and finally, so far as yet ascertained, the symmetrical condition of the genital organs, combined with the extreme shortness of the ovarian tubes, is a condition which, so far as I am aware, can only be paralleled amongst the *Anguillulidæ*. After further careful search I have still failed to find any trace of vulva or vagina, and am moreover still inclined to believe, for the various reasons stated in my memoir on this animal§, that a resort to the method of *agamogenesis* to account for the production of its countless young, is not only most in accordance with what we know of the history of this animal whilst in the human body, but also most consistent with the fact of the existence of young in the genital tube in all stages of growth, from

* Trans. of Linn. Soc. vol. xxv. p. 126.

† Or, at all events, unrecognizable.

‡ *Oxyuris ambigua* of RUDOLPHI.

§ Trans. of Linn. Soc. vol. xxiv. p. 126.

the smallest germ upwards, at periods when the parent must have been actually within the cellular tissue of the human body for no less than eight, nine, or even more months*.

In all the species of the genus *Dorylaimus*, before the animals have attained their full adult size, a reserve spear may always be observed imbedded in the anterior portion of the œsophagus, just posterior to the one *in situ* and slightly larger than it. This reserve spear seems to have no special connexions of any kind; it appears to be simply lodged in the substance of the œsophagus, and not even a containing sac can be detected. In the progress of growth of the animal the reserve spear gradually approximates to the position occupied by the other, and at last displaces it, as the permanent tooth supplants its temporary predecessor. What causes the reserve spear to rise, or how the movement is effected, I am quite unable to say. Neither do I know how many times a spear is thus displaced during the progress of the animal towards maturity. Being of a horny nature and cylindrical in form, it is perhaps itself incapable of growth, and therefore spears of successively larger size are produced, to keep pace with the increasing dimensions of the animal.

From what I have seen of the anatomy of that form of the so-called *Filaria piscium* infesting the common Haddock, I am quite convinced that it really is most closely allied to *A. osculata* and *A. spiculigera*, which should all be placed, if not under a new generic name, certainly apart as a distinct subgenus. At the same time that I obtained the encysted Nematoids from beneath the peritoneal membrane of the Haddocks, I also dissected a mackerel, and having found one similar encysted animal entangled amongst its pyloric cæca, I then opened the intestinal canal, and found within it a single Nematoid entirely free and unencysted. This was half as large again as the largest of the animals found beneath the peritoneal membrane, though when submitted to the microscope it was found to be a more highly developed individual of the same species, and quite devoid of the membranous sheath-like covering with which the others were closely enveloped. Although this animal did not exhibit the three head lobes at all plainly, the four papillæ usually situated on them were distinct. The development of the lobes is therefore probably characteristic of a later period of the animal's growth. The genital organs, if present, must still have been in a very rudimentary condition. How are we to suppose this animal gained access to the intestine of the mackerel? It seems probable that this occurred either owing to the mackerel having swallowed some smaller fish in which the Nematoid existed in an encysted state (in which case we might expect the mackerel to be the proper host of this species in its mature condition), or else we must have recourse to the more improbable alternative, that one of the encysted individuals, previously to be found beneath the peritoneal membrane, had contrived in some way to penetrate the wall of the intestine in order to gain that situation requisite for its future development.

The development of the genital organs does not seem to take place very early. Spe-

* Professor LEUCKART has accepted this doctrine, since it seems most in harmony with anatomical facts, and also best explains certain peculiarities in the life-history of this parasite.

cimens of free Nematoids may frequently be seen which have attained more than half the usual adult dimensions, with well-formed tissues and a fully developed alimentary canal, though still in an asexual condition and presenting no trace of genital organs. What is the order of development of these organs in the male, and how soon the spicules appear I am unable to say, though I have been able to notice a few facts concerning the genesis of this system in the female. Its first rudiments consist of a small mass of indifferent tissue lying within the parietes of the body, opposite the future situation of the vulva, and to a certain extent pressing upon the alimentary canal*; and, as I have seen in species of the genus *Mononchus*, this gradually increases in size, more especially in a longitudinal direction, its central portion growing outwards so as to come into relation with a gradually formed aperture through the integument—the future vulva—whilst on either side it is developed into an elongated pyriform mass. So far only have I traced this process of development; the remaining steps consisting, in all probability, in the formation, on each side, of an internal cavity in what was at first a mass of solid homogeneous tissue; the continued growth and separation of the parts into ovary, oviduct, and uterus; and the final differentiation of tissue by which the textures proper to each segment are produced—these stages though easily imagined have yet to be observed.

With regard to the duration of life in the parasitic Nematoids we have, I believe, no definite knowledge; great variation in this respect would doubtless be met with in different species. Amongst the free forms, however, we do know, as pointed out by M. DAVAINE†, that the duration of the *active* life of *Tylenchus tritici* can only be from nine to ten months. In the animals of this species, too, the females die after the production of a single batch of ova‡; probably this, however, may simply be due to the necessities of their mode of existence, which is so exceptional in its nature as to render any data we may possess concerning these animals of little value for the determination either of the period of existence, or of the number of batches of ova produced by the free Nematoids generally.

POWERS OF REPAIR AND TENACITY OF LIFE.

Almost all the observations I have now to make refer to the *Anguillulidæ*, since what we know on these subjects concerning the parasitic Nematoids may be stated in a very few words.

With regard to the powers of repair in the parasitic species I believe absolutely nothing is known, but some remarkable statements have been made concerning their tenacity of life, and concerning the conditions under which development of their ova will proceed. Thus NELSON and ALLEN THOMPSON have best been able to study

* This condition may be well seen in the young of *Tylenchus* (*Vibrio*) *tritici*, where it forms what appears a clear space, with a slight displacement of the intestine opposite it, which from its shape has been termed the "lunule." The rudiments of the genital organs are seen unusually early in this species.

† Recherches sur l'Anguillule du blé niellé, Paris, 1857, p. 38.

‡ This may be considered as the most prolific of the free Nematoids; in this respect, indeed, as well as in the nature of its habitat, it approximates closely to its more strictly parasitic kindred.

the development of the ova of *Ascaris mystax* whilst the animals in which they were contained were immersed in oil of turpentine; whilst Professor AITKEN says he has "seen the development of the embryo proceed in spirits of wine for about three weeks before signs of vitality had ceased." In certain species of *Ascaris* it has been shown by many experiments that the ova remain in fluid occasionally for more than twelve months before they begin to exhibit any active signs of development. Many observations also tend to show that the majority of young and immature Nematoids are enabled to survive under circumstances which rapidly prove fatal to the adults. Thus, speaking of *Trichina spiralis*, Dr. COBBOLD* writes, "M. DAVAINE kept the larvæ alive in water for a month, but the adult worms perished in cold water in about an hour. Under ordinary circumstances DAVAINE'S observations lead us to conclude that the adult worms do not survive their hosts above six hours, but the larvæ will live for a long time in flesh which has already undergone putrefaction." Some of the statements made concerning the tenacity of life in the adult animals are so marvellous as to appear incredible; thus OWEN† states, "a Nematoid worm has been seen to exhibit strong contortions—evident vital motions—after having been subjected above an hour to the temperature of boiling water with a codfish which it infested." Whilst according to Dr. AITKEN‡, MIRAM has seen specimens of *Ascaris acus* from the pike "become dry, and remain sticking to a board, where they would revive again by being placed in water; and in some instances they would move a part of the body which had imbibed the fluid, whilst the remaining part continued shrivelled up and adherent immoveably to the board;" and he further adds, "I have seen the very same results in the *Ascaris* which infest the peritoneal covering of the mackerel." With regard to such powers possessed by these animals I can myself say nothing.

Passing now to the *Anguillulidæ*, I may state as the result of many experiments with these, that the power they possess of repairing injuries seems very low. I have cut off portions of the posterior extremity of the body of *Enoplus communis*, and though I have watched the animal for days after could never recognize any attempt at repair. And, as a general rule, when the bodies of any of the larger marine species are severed, both fragments of the body will continue to move for from three to five days, though during this time neither of the cut extremities shows the slightest signs of repair. For the last day or two the fragments move only when irritated, and finally they cease to respond even when roughly touched§. Within twenty-four hours of this time their bodies may be seen

* Entozoa, 1864, p. 34. † Lect. on Comp. Anat. 1855, p. 116.

‡ Science and Practice of Medicine, vol. ii. p. 126.

§ It seems possible that in some cases the anterior half of the body may survive much longer from a consideration of the following facts. On April 5, 1864, I found in a wide-mouthed bottle containing salt water and a very small quantity of a filamentous green seaweed, the anterior half of a specimen of *Oncholaimus vulgaris*, quite active in its movements, though presenting no traces of repair. It seems almost certain that the injury to this animal must have been done on or before the 24th of the preceding month (March), since the water and weed were put into the bottle on that day, and had not been interfered with in the meanwhile. Neither were there any larger animals in the bottle capable of biting the *Oncholaimus* in two.

swarming with myriads of minute monads, to which the next day may be added larger infusory animalcules; together, these proceed rapidly with the work of demolition, and in the course of a few days leave only the chitinous integumentary sheath of the Nematoid as the remnant of their feast.

The revival of animals after complete desiccation was first observed amongst the Rotifera by LEEUWENHOEK in 1701, and his observations were subsequently repeated by many other naturalists during the next half century, the principal of whom were HILL, BAKER, FONTANA, GÖZÉ, CORTI, OTTO MÜLLER, and the ABBÉ SPALLANZANI. The discovery, by NEEDHAM, in 1743 of the young Anguillulæ in what appeared to be diseased grains of wheat*, added another animal to the list of those possessing this remarkable power of *reviviscence* after prolonged periods of desiccation; and very shortly after this the number was still further increased by SPALLANZANI discovering that, in addition to the Rotifera in tufts of moss, there were certain Anguillulæ and arachnidal animals ("Sloths") found in the same situation, all of which were endowed with a similar tenacity of life.

One of the most interesting facts that has yet been made known concerning the so-called *Vibrio tritici* was ascertained by BAKER. He discovered that some of these animals contained in diseased wheat, given to him by NEEDHAM in 1744, still possessed the power of resuming all their vital manifestations, after immersion in water, in 1771; that is to say, after a period of twenty-seven years†. This is the longest period on record, and several observers have failed to restore them after much shorter intervals. Thus with wheat of a certain year's growth, BAUER‡ could not revive these animals after five years and eight months; whilst with that of another year he met with the same failure after six years and one month. My friend Mr. W. H. INCE tells me that he has seen them revive from specimens of wheat which had been kept "about twenty years." The varying periods during which these Nematoids retain this power of reviviscence in all probability depends very much upon the manner in which the "galls" have been preserved

* The Nematoid (*Tylenchus tritici*) producing this disease of wheat, known as "purples" or "ear-cockle," is not contained in a real seed but in a gall-like growth replacing this. For further particulars on this subject see DAVAINE's 'Recherches sur l'Anguillule du blé niellé,' p. 20, and the "Monograph on the Anguillulidæ," Trans. of Linn. Soc. vol. xxv. p. 87.

† Lettre de NEEDHAM en réponse au mémoire de Roffredi, dans 'Journ. de Physiq.' t. v. p. 227, 1775. At one time SPALLANZANI believed that these were not real animals, but merely "filets allongés et mis en mouvement par le fluide qui les pénètre" (Nouv. Recherch. sur les découv. Microscop. &c., Annot. par Needham, part 1. p. 25, Paris, 1769); in this belief he was for a time followed by NEEDHAM. Both OKEN and RUDOLPHI (Grundr. der Physiolog. 8vo, 1821–27) deny the fact of the revival of animals after desiccation, whilst BORY DE SAINT-VINCENT and DUGÈS deny its occurrence in the *Vibrio tritici*. Even DIESING, writing as late as 1851, makes the following statement on this subject:—"Animalcula exsiccata, iterum humectata post annos reviviscere narrant cel. BAUER et HENSLOW, phænomenon rectius forsan motu *moleculari explicandum*" (Syst. Helminth. t. ii. p. 132). And even amongst those who admit the fact of the reality of the powers possessed by these animals of recovering after periods of desiccation, most various statements have been made by recent writers; thus COBBOLD states that they are capable of recovering after "two or three years" of desiccation, whilst Professor AITKEN (Sc. and Prac. of Med. 1863, vol. iii. p. 126) even puts the period as low as from "four to seven days."

‡ Philosophical Transactions, 1822.

during the interval; much in the same way as the length of time that seeds are capable of retaining their power of germination, is greatly influenced by the method of their preservation—by variations in their hygrometrical condition, and degree of exposure to the air.

It was first observed by SPALLANZANI that one of the essential conditions for the revival of the Rotifers and Anguillules found in tufts of moss was, that their period of desiccation should either be passed in these tufts, or else that during the same time their bodies should be more or less covered with sand*. His explanation of this fact was that the access of air exercised a prejudicial influence upon the delicate structures of these animals. The fact is quite in accordance with my own observations, and as regards its explanation, I am able to offer nothing more satisfactory than that advanced by SPALLANZANI. He alternately dried and moistened the same animalcules twelve times with similar results, except that the number of the revivers was successively smaller each time, but after the sixteenth moistening he failed to restore any of them to life†.

Since SPALLANZANI's time the most interesting experiments concerning the power of reviviscence in the Anguillulidæ have been made by M. DAVAINE‡ and by MM. DOYÈRE and GAVARRET§. I shall briefly notice some of the principal results arrived at by these experimenters before detailing my own observations on this subject.

DAVAINE ascertained that the time of saturation in water necessary for the recovery of the young of *Tylenchus tritici*, was not directly proportional either to the length of their period of desiccation, or even to the actual degree of desiccation to which they had been submitted. With regard to the length of the period of desiccation he adds, "il y a, sous ce rapport, moins de différence entre les larves d'un an et celles de quatre ans, qu'entre les larves d'un mois et celles d'un an." To ascertain the influence of the degree of desiccation upon the time necessary for their recovery he made the following experiments. Larvæ three years old were taken, and placed under the receiver of an air-pump, together with a large capsule containing concentrated sulphuric acid to absorb all aqueous vapour; the air was then exhausted as completely as possible, and the animals allowed to remain *in vacuo* for five days. Then when withdrawn and immersed in pure water, most of them resumed their activity and vital manifestations after a period of three hours. Subsequent experiments convinced him that larvæ, varying from one to three years old, invariably recovered as quickly after they had been completely desiccated by a sojourn of four days in a vacuum, as did others of the same age that had merely been exposed to the air for a similar period. In grains which have been gathered only a few days the animals may be revived in less than an hour; in those which have been kept four years in not less than ten, fifteen, or twenty hours. It is quite improbable, however, that these last could be so dry as fresh grains which had been preserved in a

* Tracts on the Nat. Hist. of Anim. and Veget. Transl. by DALYELL, vol. ii. (ed. 2) p. 129 *et seq.*

† OWEN's Lect. on Comp. Anat. 2nd ed. p. 54.

‡ Recherches sur l'Anguillule du blé niellé, 1859, pp. 39–61.

§ Ann. des Sc. Nat. 4me sér. t. xi. 1859, p. 319.

vacuum with sulphuric acid for four days, and whose contained young even after this process may be revived in less than an hour. The time during which they are allowed to remain active considerably influences their future power of reviviscence; thus, DAVAINE finds, "Après un mois du séjour dans l'eau, la plupart des anguillules desséchées ont encore la faculté de revenir à la vie. Passé ce temps, elles perdent assez promptement cette faculté. Aussi lorsqu'on met dix jours d'intervalle entre chaque dessication nouvelle, dès la quatrième revivification l'on voit le nombre de celles qui restent mortes augmenter rapidement. La durée du temps pendant lequel on garde ces animaux en état de dessication a peu d'influence sur ce résultat, qui dépend en grande partie de *la durée de la vie active*." DAVAINE insists upon the fact that organic matter of any kind undergoing decomposition in the water in which desiccated animals are immersed, will absolutely prevent their exhibiting any movements or signs of life. They remain stiff, straight, and motionless, though not in reality dead; and from other experiments concerning the noxious properties of even the minutest quantity of ammonia mixed with the fluid containing these animals, he supposes that the deleterious influence of decomposing organic matter may in reality be due to the evolution of minute quantities of ammonia. For interesting details on this subject, and also on the influence of solutions of various poisonous and narcotic alkaloids, I must refer to M. DAVAINE'S interesting memoir. He also dwells upon what I am able to confirm, viz., the fact that the remarkable powers possessed by the young are not shared by the adult *Tylenchus tritici*, which does not exhibit any very well-marked tenacity of life. As I shall point out afterwards, however, this is quite exceptional, and is in all probability due to the method of existence of this animal, since in other species of the genus *Tylenchus* both old and young are similarly endowed in this respect. Elsewhere* M. DAVAINE having become aware of the fact that all the Anguillulidæ do not possess this same tenacity of life, made a general statement on the subject which comes very near to the truth; he thinks that those species which are constantly submerged do not possess this property of recovering even after short periods of desiccation, whilst it is possessed by others, "qui vivent dans les lieux exposés aux alternatives de sécheresse et d'humidité." This is a considerable advance upon the popular opinion, which has hitherto regarded all the free Nematoids as endowed with the same remarkable tenacity of life; although in the right direction, it is, however, too sweeping a generalization.

The experiments which were conducted in concert by MM. DOYÈRE and GAVARRET upon the degree of tenacity of life of the Rotiferæ and Anguillulidæ found in tufts of moss are of the greatest interest, and the results of their inquiries may be accepted with all the more satisfaction, from the very evident care and caution with which these experiments were conducted. Their paper should be studied by all interested in this question, so startling are its results, and so opposed to all ordinary biological data. I cannot refrain from quoting here the results of one carefully performed series of experiments, instituted to ascertain the power of resisting simple desiccation at ordinary temperatures

* Ann. des Sc. Nat. 4me sér. x. 1858, p. 387.

possessed by these animals. Their words are, "En résumé ces mousses étaient restées *soixante-sept* jours dans un armoire du cabinet de physique de la Faculté de Médecine (du 21 juin au 27 août), avaient subi pendant *deux* jours l'action de *l'air sec* (du 27 au 29 août), et pendant *cinquante et un* jours l'action du *vide sec* (du 29 août au 19 octobre); elles étaient si *complètement desséchées*, qu'en *quatre* jours d'exposition à la double influence du vide et de l'acide sulfurique (du 15 au 19 octobre) elles n'avaient rien perdu de leur poids; néanmoins *vingt-quatre heures de simple hydration* ont suffi pour rendre *toute leur activité* aux rotifères, aux tardigrades (*Emydium*, *Macrobiotus*), et aux anguillules de ces mousses" (*loc. cit.* p. 319). Unfortunately other interesting results arrived at concerning the influence of heat upon these previously desiccated animals refer to the two former varieties only, since no Anguillulidæ, either living or dead, were seen in these later experiments. The other animals recovered after being submitted for a few moments to a dry heat of more than 212° F. According to M. Davaine, however, the young of the *Vibrio tritici* completely lose their vitality when submitted in the same way to a dry heat of 160° F. Their power of resisting low temperatures is most remarkable, since he says they will recover their vital manifestations after being subjected to a temperature of 0° F. for eight or ten hours.

So far as my own observations have gone at present, I find that amongst the *Anguillulidæ* this remarkable tenacity of life of which we have been speaking, is met with only amongst the representatives of four land and freshwater genera, *Tylenchus*, *Plectus*, *Aphelenchus*, and *Cephalobus*; whilst those of all the other genera excepting *Rhabditis*, marine as well as land and freshwater, are rather remarkable for the very opposite characteristic, they being incapable of recovery even after the shortest periods of desiccation*. Very many of the species of these four genera are found in earth, lichen, moss, or other situations in which they are exposed to constant vicissitudes of drought and moisture according to ever changing meteorological conditions, and in the possession of this power of resisting the effects of desiccation they exhibit the most admirable adaptation for neutralizing what would otherwise be the fatal influence of the varying condition of their environment. Their whole life-history must be a strange one, made up of periods of life and activity alternating with others of potential death —the two states bearing no definite relation to one another as regards duration, being altogether inconstant and variable, and succeeding one another under the influence of laws so remote, as to make the successions of active and passive existence in these animals almost a matter of chance. Doubtless they have a certain *definite span of active existence*, in which to go through the stages of development and growth, and provide for the con-

* In connexion with this statement I would call attention to the fact that, when water is added to these animals in a state of desiccation, a deceptive appearance is produced which might mislead a hasty observer. The more or less rapid imbibition of fluid into the bodies of these animals produces a few momentary contractions of the body, which, though really due to purely physical causes, are sufficiently simulative of vital movements. I think it must have been movements of this kind which led Otto Müller (Anim. Infusor.) to assert that certain marine forms did possess the power of recovery after desiccation. If this is not the case, then his observations are quite irreconcileable with what I have myself seen.

tinuation of their kind by the ordinary processes of reproduction. Whilst the sum total of these periods of active life, peculiar and necessary to the species, is in all probability pretty definite, the period of time over which its fragmentary existence may be extended is altogether variable and indefinite, owing to the uncertain length and number of the interpolated periods of desiccation and apparent death. Whilst we meet with this admirable adaptation to external conditions in the animals of these genera, there are many species of the genera *Mononchus* and *Dorylaimus* found in some of the same situations, which are nevertheless frail and incapable of resisting desiccation. Many species of the genus *Plectus* also are to be met with which do lead a constantly submerged existence, and to whom therefore this remarkable tenacity of life would not be a matter of so much importance. These facts show that M. DAVAINE'S conclusions on this subject were drawn from insufficient data.

An examination of tufts of moss from the roofs of houses* or from old walls, as well as of specimens of the yellow lichen, *Parmelia parietina*, from the same situations, has invariably revealed to me three principal kinds of animal occupants—specimens of Rotifers, of peculiarly slow-moving arachnidal *Tardigrada*†, and two or three different kinds of *Anguillulidæ*. Precisely the same varieties of animal life are spoken of as existing in the tufts of moss examined by SPALLANZANI, and also in those which were experimented upon by DOYÈRE and GAVARRET. Moreover I have found specimens of lichen brought from Sweden tenanted by just the same types. In all the specimens of moss and lichen of the kind above mentioned that I have examined, I have invariably found that the free Nematoids present were representatives of my two genera *Plectus* and *Aphelenchus*. It seems therefore highly probable that the so-called "Anguillulæ" of preceeding observers were also representatives of these genera. The specimens met with were of very different ages, many containing well-developed ova within them, and the property of reviviscence seems common to old and young alike. Possibly there may be a slight difference in the degree of tenacity of life enjoyed by the immature and the adult animals respectively, but, at all events, no notable difference exists, such as we have ascertained to be the case with *Tylenchus tritici*. After what has already been said, it would be useless for me to give further details concerning the powers of resisting the effects of prolonged and complete desiccation possessed by these animals whilst still in their natural habitat, whether this be sand, moss, or lichen, but I can add a few interesting facts concerning the extreme curtailment of this power when the animal is allowed to undergo the process of desiccation on a slip of glass, isolated from all other materials and thus freely exposed to the air; and also concerning the results of other experiments, made with free Nematoids not belonging to one of the four genera before named.

In submitting the animals to these tests, I was careful to select active uninjured

* Belonging to the genus *Tortula*: often found in hemispherical masses.

† For some particulars concerning the anatomy of these singular animals see Archiv für Microsk. Anat. erste Band, 1865.

individuals, which were then removed carefully on the point of a feather and placed on a clean slip of glass.

After specimens of species belonging to either of the four genera *Tylenchus*, *Plectus*, *Cephalobus*, or *Aphelenchus* had been thus laid on the slip of glass, the time noted, and the animals submitted uncovered to the microscope, I found them lose their form and begin to shrivel only very slowly, and also that after the allotted period of exposure to the desiccating influence of the air was over and some water was added, this seemed to penetrate their bodies very slowly—the gradual process of redistension often occupying nearly thirty minutes before the animal was quite restored to its original form. The length of time required, however, depends upon and increases with the duration of the period of exposure, and, in almost all cases, after the animal has regained its habitual form it remains for a variable time perfectly still and motionless. In experiments* with *Plectus parietinus*, I have found that if the period of exposure has been from one to four or five hours, the perfect redistention of the body usually occurs in about twenty-five minutes, and then the slow bending movements which are the first evidences of returning activity may begin almost immediately afterwards. As a rule, after an exposure of forty-eight, or even thirty-six hours, the animals never recover at all. Exceptions, however, occur: thus, I once saw an animal recover after it had been exposed for five days, though in this case the recovery was proportionally slow, the animal not having completely resumed its natural appearance till four hours after the addition of water, and not having commenced its first slow movements till after the expiration of another two hours. Occasionally the animals do not recover after much shorter periods of exposure than that mentioned above, and sometimes the resumption of activity after the addition of water is much more speedy than usual; thus, in one instance, an animal which had been exposed and dry for twenty-one hours, was seen in full activity only eight minutes after the addition of water. So far as I have seen, young specimens are certainly not capable of resisting exposure better than, or even so well as adults.

When we remember the power these same animals possess of resisting prolonged and complete desiccation *in vacuo*, as shown by the experiments of MM. Doyère and Gavarret, it is most striking to find them succumbing in such short periods to the mere desiccating influence of the atmosphere upon their *uncovered* bodies. How can we explain this without imagining the direct contact of atmospheric air to have a deleterious influence upon their tissues?

With animals belonging to the genera *Chromadora*, *Enoplus*, *Monhystera*, *Leptosomatum*, *Mononchus*, *Dorylaimus*, and many others, the results have been almost uniform. I have never succeeded in restoring any of these animals after they have remained dry and motionless on glass for two minutes; many would not recover after one minute of such exposure, and with *Chromadora communis* I have rarely been able to revive specimens after even half a minute's exposure, dating from the time of the *cessation of movement in the drying animal* as seen under the microscope. All these animals shrivel

* Temperature of room (summer) $70\frac{1}{2}°$ F.

more quickly than those of the other four genera when thus exposed; and when water is added its imbibition, instead of being slow and gradual, is almost instantaneous, giving rise to a few contractions and movements which are at first simulative of returning vital movements. But this temporary activity almost immediately subsides, and then, though watched for many hours after, no movements can ever be discerned.

The members of the genus *Rhabditis* seem to occupy a kind of intermediate position. Thus, I have succeeded in reviving some specimens after fifteen minutes' exposure on a slip of glass, but in the few trials I have made, have never succeeded in doing the same after they have been exposed for twice that time. In their anatomy, also, these animals are somewhat allied to those of the four genera above mentioned, and the nature of their habitats being much the same, this remarkable tenacity of life is useful to all alike.

It seems to me that the increased tenacity of life exhibited by the members of the four genera *Tylenchus*, *Aphelenchus*, *Plectus*, and *Cephalobus*, is partly connected with the power they possess of retaining their tissues in a moist condition for a longer time than the others, owing to the comparative, or even total absence in them of the integumental pores which appear to be present in most of the other species of free Nematoids. This view is supported by what I have just stated of the difference in the rapidity of imbibing fluid exhibited by desiccated animals belonging to these two classes, and is still further borne out by other observations tending the same way. Thus I have seen adult specimens of *Tylenchus tritici*, when immersed in strong glycerine, instead of shrivelling up almost immediately as the great majority of free Nematoids would do, continue to swim about for twenty minutes in this dense medium before any shrivelling of their bodies took place. Moreover, I have immersed them, as well as specimens of the genera *Plectus* and *Aphelenchus*, in a magenta colouring solution and taken them out of it after the same period alive and active, and with their bodies perfectly uncoloured save for a very short distance from mouth, anus, or vulva; whereas other species not belonging to one of these four genera would have had their whole bodies perfectly coloured, and have been dead in two or three minutes. *Plectus parietinus*, however, only resists the glycerine for a minute or so, though it may remain alive in the magenta solution for half an hour and then only have the anterior portion of its œsophagus coloured, together with the external parts of the rectum and vagina, and the narrow portions (Plate XXVIII. fig. 14, *b′*, *b′*) of the vessels in communication with the lateral cervical spaces*.

This power can, however, be looked upon only as a mere accessory contributing to the greater hold on life possessed by these animals, as it fails to account for facts, when we take into consideration the prolonged periods of ordinary desiccation—to say nothing of absolute desiccation *in vacuo*—which these animals will undergo and still recover. It is not only that they have this power of resisting the effects of desiccation, but they are

* It is this fact which makes me imagine that these spaces must be perforated, although I have been unable to detect apertures even with the highest magnifying powers. May not these vessels be homologous with the more abortive, lateral, excretory tubes of *Leptosomatum elongatum* (Trans. of Linn. Soc. vol. xxv. pl. 12. fig. 156), since we know for certain that the similar vessels of *Tylenchus tritici* terminate posteriorly in cæcal extremities?

also capable of resisting the effects of many other agents which would speedily prove fatal to others of their kindred not similarly endowed. There seems to be some innate, though inscrutable difference in the intimate constitution of their tissues, into the nature of which we may never be enabled to penetrate, even with the most perfect instrument the optician could devise.

ZOOLOGICAL POSITION AND AFFINITIES.

Having now pretty fully explained the anatomy of the Nematoids, we shall be able, with the aid of the many new facts revealed concerning their structure, to consider the question of their affinities and homologies with more chance of success than formerly, so that we may hope to throw some light upon this difficult subject. Hitherto, to those anatomists who penetrate beyond mere external form, the Nematoids have been regarded almost as an outlying group, having no definite relationship with other animals, and admitting only of a provisional location in the convenient though utterly artificial class Entozoa. In the first volume of his 'Elements of Comparative Anatomy' recently published, Professor HUXLEY has done much to elucidate the homologies of the "Annuloid" animals; and as well from the philosophic nature of his views as from the fact that he is the latest writer of note who has treated on the classification of the Animal Kingdom, it seems desirable for me briefly to refer to some of these views in order that we may be able more fully to appreciate the state of the question concerning the affinities of the Nematoids.

In his 'Lectures on General Natural History'* he divided the subkingdom ANNULOSA into two great divisions, the ARTICULATA or ARTHROPODA and the ANNULOIDA; including in the former division *Insecta*, *Myriapoda*, *Crustacea*, and *Arachnida*, whilst in the latter he placed *Annelida*, *Echinodermata*, and *Scolecida*—the latter being a name under which he still proposes to include the *Entozoa*, *Turbellariæ*, and *Rotiferæ*.

In the recently published work†, however, this classification is somewhat modified; since whilst acknowledging that "the members of the class *Annelida* present marked differences from all the Arthropoda, but resemble them in one important particular, and that is the arrangement of the nervous system, which constitutes a ganglionated double chain traversed at one point by the œsophagus," still he now thinks "that the resemblances between the *Annelida* and Arthropoda outweigh the differences, and that the characters of the nervous system and the frequently segmented body, with imperfect lateral appendages of the former, necessitate their assemblage with the Arthropoda into one great division or subkingdom of ANNULOSA."

Whilst laying little stress now upon the few resemblances of the Echinoderms and Scolecids to the Annelids, such as the occasional resemblance between their ciliated larvæ, and the possibility of the vessels of the Annelids being modified representatives of the water-vascular apparatus, he thinks there can be no doubt as to the many singular resemblances which unite the Scolecids and the Echinoderms together. And whilst

* Med. Times, 1856, ii. p. 27.

† On the Elements of Comp. Anat. 1864, p. 75.

partly admitting the difficulty of the different arrangement of the nervous system in these two classes, he says, speaking of the ambulacral system in the Echinoderms and the water-vascular system in the Scolecids, "It is impossible to compare these two systems of vessels without being struck by their similarity; each is a system of canals opening externally and ciliated within, and the circumstance that the two apparatuses are turned to different purposes in two distinct groups of the animal kingdom, seems to me no more to militate against their homology, than the respiratory function of the limbs of Phyllopod *Crustacea* militates against the homology of these limbs with the purely locomotive appendages of other crustaceans." Uniting these two classes together still under the name of ANNULOIDA, Professor HUXLEY now thinks it would be better, instead of retaining this as a division of the subkingdom ANNULOSA, to elevate it, in like manner, to the rank of a "distinct primary division of the animal kingdom."

Let us now turn our attention more particularly to the class *Scolecida*: in this Professor HUXLEY includes (provisionally rather than with any feeling of certainty) seven groups, "the *Rotifera* (or wheel animalcules), the *Turbellaria**, the *Trematoda* (or flukes), the *Tæniada* (or tape-worms), the *Nematoidea* (or thread-worms), the *Acanthocephala*, and the *Gordiaceæ*" (p. 47). Of these, he seems pretty confident that the first four groups have such a relationship as to demand their union in a single class on the ground of a certain similarity in the arrangement of their nervous ganglia, and from the fact of their all possessing that peculiar apparatus of vessels opening externally, which has been called a "water-vascular system," whilst no heart, or vessels of any other kind are known to exist. He imagines also that the system of reticulating canals beneath the integument of the *Acanthocephala* must be a modification of this apparatus.

With regard to the Nematoids and their near allies the *Gordiaceæ* he is more doubtful, though he says, "If the system of canals, in some cases contractile, which open externally near the anterior part of the body (fig. 22), and were originally observed by VON SIEBOLD, and since by myself and others, are to be regarded as homologous with the water-vessels of the *Trematoda*, this question must, I think, be answered in the affirmative†. It is almost the only system of organs in the *Nematoidea* which gives us a definite zoological criterion, the condition of the nervous system in these animals being still, notwithstanding the many inquiries which have been made into the subject, a matter of great doubt."

Our increased knowledge concerning the various modifications of the contractile canals in the Nematoids, and the positive nature of our information relating to the nervous system of these animals, now place us in a much more favourable position for considering the affinities of this particular group, and also tend, as I have already pointed out‡, not only to throw considerable light upon the functions of the water-vascular system, but also to bind more intimately together the two classes *Scolecida* and *Echinodermata*.

* Including *Nemertidæ* and *Planariæ*.

† As to whether the Nematoids should be grouped with the four orders before mentioned.

‡ See p. 603.

It seems to me that in the present state of our knowledge we may be justified in looking upon the *Nematoidea*, and in all probability the *Gordiaceæ*, as close allies of the *Echinodermata*, leading to and connecting these with the *Scolecida* through their affinities to the *Acanthocephala*.

In the first place, the nervous system of the Nematoids is remarkably similar to that of the Echinoderms. In all adult specimens it is described by Professor HUXLEY as "a ring-like or polygonal ganglionated cord situated superficially to that part of the ambulacral system which surrounds the mouth, and sending prolongations parallel with and superficial to the radiating ambulacral trunks"*. And elsewhere† he states that "the circle round the mouth has rather the nature of a commissure than of a ganglionic centre." Scarcely anything can be more close than the correspondence of this description with the actual condition of things fully proved to exist in certain genera of Nematoids. This similarity is especially notable as regards the characters of the œsophageal ring: the agreement is here complete, and any difference as regards the arrangement of peripheral branches is nothing more than might be expected from the diversity in external form of the respective animals. If we take next the vascular system—accepting the views propounded by Professor HUXLEY as to the probable homological identity of the water-vascular system of the *Scolecida* with the ambulacral system of the *Echinodermata*—there can be little doubt that the so-called ventral glands in some, and the much more developed system of canals in other Nematoids, each having a similar communication with the exterior, can have their homologues only in these two systems, although their relationship is much more marked to the vessels of the Scolecids than to those of the Echinoderms. In both Nematoids and Scolecids the tubes immediately communicating with the exterior have been observed contracting and dilating in a kind of rhythmical manner, and the contents of each have been seen to consist of a clear fluid containing a larger or smaller quantity of suspended molecules. And the fact that as yet no cilia have been recognized in any part of this system of canals in the Nematoids—even though they are really absent, and their non-discovery has not been due merely to the intrinsic difficulties of the investigation—seems to be no real objection, since though such ciliated prolongations in connexion with the non-ciliated contractile tubes have been distinctly recognized in many *Trematoda* and *Tæniada*, still there are some of the former, such as *Distoma excisum* observed by HUXLEY, and *Distoma tereticolle*, *D. perlatum*, and *D. nodulosum*, together with *Amphistoma subclavatum*, according to AUBERT, in which "no cilia at all exist in any part of the water-vascular system, so that in these *Trematoda* its condition is, as it were, diametrically opposed to that which it exhibits in *Aspidogaster*"‡. The method of development of these tubes in the Nematoids according to all *à priori* possibility, and also from what I have seen in the young of *Dracunculus medinensis*, appears to be similar to that by which the water-vessels of the Scolecids and the ambulacral vessels of the Echinoderms originate; and for the reasons before stated§, I think

* Elements, p. 46.

† Med. Times, 1856, ii. p. 635.

‡ Med. Times, 1856, ii. p. 133.

§ See p. 597.

we have strong evidence for the belief that the excretory gland, opening externally in the œsophageal region of many Nematoids in which, so far as yet observed, the lateral vessels are wanting, is the rudimentary homologue of this system of canals, and may be considered as a permanent record of a transitory stage in their development in other species, as well as in that of the more complex form of this apparatus usually met with amongst the Echinoderms and Scolecids. An objection that may perhaps be urged to the homology of this apparatus in the Nematoids with that of the ambulacral system in the Echinoderms, is, that the latter system opens in the dorsal region of the body, whilst the former has its exit in the ventral. To this I would reply, that, as in the Echinoderms, this system opens in the Nematoid on the same aspect of the body as the genital organs and the rectum, and considering the bilateral symmetry of these latter animals together with the terminal position of their mouth, it is a matter of indifference for the purposes of transcendental anatomy which surface of the body is considered as dorsal and which as ventral: but seeing that these systems in the Echinoderms open undoubtedly upon the dorsal aspect of the body, and that the cloacal aperture of the same system is in a similar situation in the Rotifera (one of the groups of *Scolecida*), it seems pretty evident that in a developmental and homological point of view, that which has hitherto been spoken of as the ventral aspect of the Nematoids should be considered in reality as the dorsal. So far as the structure of the nervous system of the Nematoids is concerned, it also lends support to this view, since undoubtedly a much larger number of ganglion-cells are situated on what has hitherto been described as the ventral part of the œsophageal ring than can be met with in connexion with its opposite half. But the preponderance of ganglionic nervous matter in an œsophageal ring is usually *on* instead of beneath the œsophagus. The position of the ocelli in the free Nematoids is the only fact seeming to militate against this view; but I think this objection cannot be allowed much weight, seeing that the ocelli appear to be comparatively trivial organs which may be present or absent even in species of the same genus.

In the Echinoderms and in certain genera of free Nematoids there remain, however, certain other vessels which have not yet been accounted for. In the former animals I allude to that apparatus of vessels which is generally described as their "vascular system," and concerning which our knowledge is still somewhat defective. It is not absolutely proved that this is quite distinct from the ambulacral system, and our knowledge of the way in which it is developed is also obscure. Nothing more definite can at present be said of the simple lateral vessels existing amongst the free Nematoids in the genera *Tylenchus*, *Aphelenchus*, and *Plectus*, I could only ascertain that such vessels exist, and in *Tylenchus* at least, without the shadow of a doubt, that they float free from the integuments along either side of the abdominal cavity. Whether they communicate with one another, or with the exterior could not be ascertained, though, as before stated, there is slight evidence to show that in the genus *Plectus* these tubes do communicate with the exterior, each by means of a lateral, cervical, integumental pore*.

* See note, page 619.

In these lateral vessels, even when they were fairly exposed to view by being squeezed out from the cavity of the body of adult specimens of *Tylenchus tritici*, no granules or cilia could be detected; they appeared to me to contain a colourless fluid, though DAVAINE* described it as "légèrement rougeâtre," and also spoke of the lateral vessel itself as "susceptible de contractions et d'expansions alternatives et lentes."

The Echinoderms have long been remarkable for the number of pores of different kinds, opening either through their calcareous external skeleton, or through their coriaceous integument as existing in the *Holothuriadæ*; and from what I have made known in the earlier portion of this memoir concerning the prevalence, and in some species amazing number of integumental channels met with in the Nematoids, it becomes an interesting question to ascertain whether any resemblance, either as regards distribution or function, can be traced between these structures in the two groups of animals.

In the Echinoderms these pores are of three kinds; first and by far the most numerous are the so-called "ambulacral pores," mostly arranged in double series along the five pairs of ambulacral avenues radiating from the mouth and destined to give exit to the tubular feet in connexion with the ambulacral vessels. In some Echinoderms these are the only kind of pores existing, but in the *Asteriadæ* there are on the antambulacral surface other pores through which protrude small ciliated tubes imagined to have a respiratory function. In the Starfishes these are generally aggregated into groups†. Pores probably having a similar function are met with also in some Crinoids; "but it is in the Cystideans that this system of antambulacral pores attains its greatest development"‡. Still other pores, larger and definite in number, have been met with in the Echinoderms. Professor FORBES, speaking of *Cribella oculata*, one of the Asteriadæ, said:—"It received its name of *oculata*, either on account of the moniliform pores, or the five dark spots which occasionally mark the origin of the rays. The pores on the surface are not characteristic of this genus only, as Professor Agassiz seems to think. They may be seen in many other Starfishes, and in the young of almost all the species. In the living animal a brownish peritoneal membrane pouts out at each pore. Are they not subservient to respiration"§? He says, moreover (p. 152), that five similar pores are to be met with in most of the Sea-Urchins. Here we have, then, amongst the Echinoderms pores subservient to two distinct uses, the one locomotory in relation with the highly developed ambulacral system of vessels, and the other respiratory, whilst of these latter there are two varieties, those of the one set being small, numerous and indefinite in number, whilst those of the other are definite and much larger in size.

In the Nematoids two varieties of integumental pores are met with: one kind consisting of the two large, lateral, cervical pores, together with the two similar latero-ventral, caudal pores, which perhaps may be analogous to those last mentioned as

* Recherches sur l'Anguillule du blé niellé, 1857, p. 26.

† SHARPEY, art. Cilia, vol. i. p. 615, and art. Echinodermata, vol. ii. p. 40. Cycl. of Anat. and Phys.

‡ HUXLEY, Med. Times, 1856, ii. p. 657.

§ Hist. of Brit. Starfishes, 1841, p. 101.

existing in the Echinoderms; whilst the other variety includes an indefinite number of much smaller integumental channels, which, as far as function goes, are in all probability also respiratory and may be analogous to the second variety, or antambulacral pores in the Echinoderms, though in their modes of *distribution* they present many resemblances to the different modifications in the arrangement of the first or ambulacral series. Seeing that the apparatus in the Nematoids supposed to be homologous with the ambulacral vessels of the Echinoderms subserves an entirely different function, and that the locomotive feet are no longer required, we can well imagine that the pores developed in connexion with them in the Echinoderms would be unrepresented in the Nematoids. Either, then, the pores existing in the Nematoids may be considered as the homologues of the ambulacral pores, with which they exhibit so close a correspondence in the method of their distribution though subservient to a different function, or, these being absent altogether, we may suppose their vacant place and method of distribution (so characteristic of the Echinoderm type) to have been appropriated in the Nematoids by the representatives of the respiratory antambulacral pores of the Echinoderms. The arrangement of the ambulacral pores in the Echinoderms is generally along lines radiating from the mouth; and though five, or multiples of five, are the prevailing numbers met with amongst these animals, still in the family *Spatangaceæ* the ambulacral pores are distributed along four double lines instead of five, whilst in some *Holothuriæ* they are confined to one aspect of the body, and in others are scattered irregularly over its whole surface. So amongst the Nematoids the integumental pores may be found in some genera, such as *Oncholaimus* and *Leptosomatum*, along four longitudinal lines radiating from the mouth; in *Dorylaimus* and others along two; in *Trichosoma** along one, two, or three; in *Trichocephalus* along one widening band, and in such numbers as infinitely to exceed the 3720 ambulacral pores calculated by Professor FORBES to exist in the Common Egg-urchin; whilst in EBERTH'S *Enoplus cœruleus*† they would appear to be more sparingly scattered over the whole surface of the body.

Surely there must be some homologies between these organs existing in the Echinodermata and Nematoidea respectively. And if not, where else are we to look amongst the lower invertebrata for the representatives of these integumental pores which have been shown to be so numerous in the free and in some of the parasitic Nematoids?

All the Nematoids and almost all the Echinoderms are diœcious; and though in the majority of the latter the orifices of the genital organs are multiple, still in the *Holothuriadæ* there is only a single exit in the dorsal region of the body. As pointed out by MÜLLER, the Echinoderms never exhibit a perfect radial symmetry, and in some whole families even, such as the Spatangoids and Clypeastroids, there is an approximation to a bilateral symmetry; whilst the fact is as certain as it is remarkable, that "in the larval state * * radial symmetry is totally absent, the young Echinoderm exhibiting as complete a bilateral symmetry as annelids or insects"‡. The peculiar method by which

* EBERTH, Untersuch. über Nemat. Taf. vi. u. vii.

† *Loc. cit.* Taf. vii. 7.

‡ HUXLEY, Elements, p. 47.

the adult Echinoderm is produced from and out of this ciliated larva, affords a process of development certainly varying as much as possible from the simple and direct evolution of the young animal from the yelk-mass, such as obtains amongst the Nematoids both free and parasitic; but such differences in the method of development of apparently nearly allied animals may be paralleled by the discrepancies in this respect existing between the simple *Hydræ* and the various families of the *Compound Hydroida*, and also between the different families of Annelida. Concerning these latter Dr. CARPENTER remarks*, "In the history of the development of the several orders of the Annelida there exists a very marked diversity; for whilst the young of the *Terricolæ* and *Suctoria* do not usually issue from the egg until they have acquired the characteristic forms of the parent (although the number of segments may be subsequently augmented), the embryos of the *Dorsibranchiata* and *Tubicolæ* come forth in a state of far less advancement, and only acquire their perfect form by such a series of changes as deserves the designation of a metamorphosis."

It remains to be pointed out, as before alluded to, that although the quinary arrangement of organs and parts is so prevalent amongst the Echinoderms, it is far from being invariable; for, as remarked by Professor FORBES, "monstrous starfishes and urchins often appear quadrate and have their parts fourfold, assuming the reigning number of the Actinodermata," or Polypes. In the Nematoids, too, we meet with a quadrate mixed with a ternate type of formation. The lateral and median lines radiate crucially from the mouth and extend along the body, alternating with four great longitudinal muscles; but whilst we have here a radiate arrangement, which may also be considered bilateral, this approach to a bilateral symmetry is disturbed by the fact that the œsophageal canal in the Nematoids is almost invariably triquetrous, that the number of teeth in the pharyngeal cavity of the free Nematoids, when such exist, is generally three, and that the same number applies to the cephalic lobes of the *Ascarides*, and a multiple of it to those of the *Spiropteræ*. As another notable instance of deviation from a bilateral symmetry, may be cited the remarkably unsymmetrical distribution of the peculiar transverse pairs of vessels existing in some members of the genus *Ascaris*†.

By reason of these various resemblances, though more especially on account of the remarkable identity in the structure and arrangement of their nervous systems, I think it most in accordance with the nature of ascertained facts to look upon the Nematoids as close allies of the *Echinodermata*—more closely allied to them, in fact, than to the *Scolecida*. Whilst, however, it would be difficult to assign to the order *Nematoidea* a zoological position in either of these classes, there can be little doubt that their organization—uniting as it does, in a remarkable manner, some of the chief characteristics of

* Princip. of Comp. Physiol. 1854, p. 593.

† MÜLLER's Archiv. According to the descriptions given by MEISSNER, the departure from the bilateral and prevalence of a ternary arrangement must be still more striking amongst the *Gordiaceæ*, since he describes in these animals three great longitudinal muscles instead of four, alternating with three cellular bands apparently homologous with the lateral bands of the Nematoids.

both classes—presents an intermediate bond of union strengthening the alliance between them, and making the division ANNULOIDA a more coherent assemblage than it formerly appeared*. It seems to me, moreover, that the Nematoids approach the Scolecids principally through their affinities to the order *Acanthocephala*. For after a comparison of the various descriptions given of the anatomy of the *Acanthocephalæ*, their deep integumental layer with its four cord-like developments, its system of vessels, and communicating lemnisci, seem to me to find almost an exact parallel in the corresponding structures of the Nematoids; whilst their nervous system, instead of exhibiting the ring-like form met with in the Nematoids, consists of a single ganglion from which peripheral branches are sent off, thus conforming pretty closely with what must be considered as the typical form of this system in the class *Scolecida*. And, again, whilst the *Acanthocephalæ* agree with the Nematoids in being diœcious, they approximate to the *Tæniadæ* by the absence in both of all vestiges of the organs of digestion.

All attempts hitherto to subdivide the order *Nematoidea* into families and subfamilies have been more or less unsatisfactory, and at present our knowledge concerning the anatomy of the representatives of so many genera is in such a defective condition, that it would be quite useless to attempt to produce anything more satisfactory. As a provisional classification, I think that of DUJARDIN is the best; and I further desire it to be understood that I look upon the present location of the free Nematoids in a distinct family as a mere temporary arrangement, which will ultimately have to give place to a more philosophical rearrangement of all the genera composing the order. Any such classification of the genera must, I think, be based principally upon the presence or absence of the ventral excretory system, its various modifications in those genera in which it is found, and the arrangement of the integumental pores where it is absent. As characters of secondary and tertiary importance, I should regard the arrangement of the organs of generation, and the variations in the nature of the pharynx and œsophagus.

EXPLANATION OF THE PLATES†.

PARASITIC NEMATOIDS.

PLATE XXII.

Fig. 1. Anterior extremity of a *Dispharagus* from the gizzard of *Colymbus septentrionalis*, dorsal aspect:—*a*, *a*, lateral head-lobes; *b*, elongated pharynx; *c*, œsophagus; *d*, œsophageal ring of doubtful nature; *e*, *e*, lateral integumental processes.

Fig. 2. Posterior extremity of same, ventral aspect:—*a*, *a*, lateral caudal pores; *b*, *b*, lateral bands in profile.

* If, as seems probable, further investigations should make it desirable to place the orders *Nematoidea* and *Gordiacea* apart, in a distinct class, I would propose for this the name PSEUDHELMINTHIA as a suitable designation.

† Through a mistake on the part of the artist, only discovered when it was too late to be altered, the arrangement of the figures in these Plates is quite different from what I had intended. Some of the defects will be pointed out in footnotes, so as to rectify the faulty arrangement as much as possible.

Fig. 3. Anterior extremity of same, lateral aspect:—letters *a–e* same as in figure 1; *f*, mid-ventral pore; *g*, rudimentary gland in connexion with same.

Fig. 4. Anterior extremity of a half-grown specimen of *Ascaris spiculigera*, showing lateral cervical pores (*a*, *a*,) and one of smaller intermediate head-lobes.

Fig. 5. Ventral aspect of posterior extremity of same specimen:—*a*, *a*, lateral caudal pores opening into well-marked surface depressions; *b*, anal cleft; *c*, *c*, lateral bands.

Fig. 6. Anterior extremity of *Ascaris piscium*, from the Haddock:—*a*, *a*, two of the four head papillæ; *b*, left lateral band; *c*, its axial unbranched vessel, which opens externally at *d*.

Fig. 7. External aspect of lateral band and its contained vessel, more highly magnified:—*a*, *a*, large, highly refractive particles in the band itself; *b*, undulating axial vessel, with an appearance of imperfect septa or bridles at intervals.

Fig. 8. Transverse section of same species, showing vessel in left lateral band only, and thick glandular walled intestine (*a*) as in Plate XXVI. fig. 10.

Fig. 9. Contiguous portions of œsophagus and intestinal canal of same species, showing an œsophageal cæcum directed posteriorly (*a*), and an intestinal cæcum anteriorly (*b*).

Fig. 10. Lateral aspect of anterior extremity of *Heterakis vesicularis*:—*a*, mid-ventral pore communicating with a wide tube; *b*, much narrower lateral band.

Fig. 11. Anterior extremity of *Heterakis acuminata*:—showing (*a*) a large transverse mid-ventral aperture in communication with the dilated extremity of an excretory tube.

Fig. 12. Portion of integument of same, more highly magnified, showing two of lateral pores.

Fig. 13. Posterior extremity of male of same species:—*a*, single slipper-shaped spicule; *b*, *b*, well-marked ventral suckers; *c*, *c*, integumental channels; *d*, *d*, pale internal bands, probably muscular; *e*, seminal tube; *f*, intestine.

Fig. 14. *Ascaris lumbricoides*, dorsal aspect of anterior extremity:—*a*, *a*, anterior latero-cervical pores; *b*, *b*, suctorial papillæ of dorsal head-lobe; *c*, *c*, large pores on latero-ventral head-lobes; *e*, *e*, *e'*, fine channels through the anterior borders of the head-lobes; *f*, *f*, lateral bands in relation with the cervical pores.

Fig. 15. Ventral view of the posterior extremity of the same:—*a*, anal cleft; *b*, *b*, latero-ventral caudal pores; *c*, *c*, lateral bands.

Fig. 16. One of cervical integumental channels, more highly magnified.

Fig. 17. Side view of a portion of dorsal head-lobe:—*a*, chitinous portion of integument; *b*, one of suctorial papillæ; *c*, deep cellulo-granular layer of integument.

Fig. 18. Side view of a portion of one of latero-ventral head-lobes:—*a* and *c*, same as in last figure; *d*, large pore; *e*, one of anterior, fine integumental channels.

Fig. 19. Anterior extremity of same, lateral aspect:—*g*, ventral pore; *h*, sheath of exit-tube of lateral vessels. Other references same as in fig. 14.

Fig. 20. Posterior extremity of male of same species, lateral aspect, showing the series of suctorial papillæ of one side of body (*a*, *a*, *a*, *a*); *b*, one of posterior latero-ventral pores; *c*, larger of two spicules, protruded.

Fig. 21. Magnified view of surface of integument, corresponding to one of these ventral papillæ:—*a*, central aperture leading to apex of papilla; *b*, slightly concave depression in which it is situated; *c*, linear markings of integument.

Fig. 22. One of bladder-like developments from muscle-cell of *Ascaris lumbricoides*, highly magnified*.

Fig. 23. Anterior portion of body of *Ascaris megalocephala* slit open in the dorsal line, the head-lobes cut off and œsophagus removed:—*a*, *a*, lateral bands; *b*, dorsal median line; *c*, ventral median line; *d*, position of œsophageal band of nervous system; *e*, arch of excretory vessels; *f*, mid-ventral orifice.

PLATE XXIII.

Fig. 1. Transverse section of the integument of *Ascaris lumbricoides* posterior to the termination of œsophagus:—*a*, chitinous portion of integument; *b*, deep cellulo-granular layer; *c*, *c*, median lines; *d*, *d*, lateral bands; *e*, *e*, axial vessels or ducts.

Fig. 2. Transverse section of the entire animal, slightly anterior in position to that of last figure:—letters from *a*—*e* same as in last figure; *f*, *f*, *f*, *f*, sections of the four great longitudinal muscular bands; *g*, *g*, *g*, *g*, the four sets of transverse muscular fibres, proceeding from the muscle-cells to the median lines; *h*, *h*, bladder-like developments from the muscle-cells; *i*, transverse section of intestine.

Fig. 3. Transverse section of the male about $1\frac{1}{4}$ inch from its posterior extremity. Letters *a*–*i* same as in last figure. The lateral bands are here seen above the median horizontal plane of the body, and arising from them are strong muscular processes, latero-ventral (*k*, *k*), chiefly proceeding to the muscles on either side of the mid-ventral line; *l*, *l*, latero-ventral papillæ at their greatest distance from one another; *m*, male genital tube. The axial canal of the lateral band cannot be recognized in transverse sections of this region

Fig. 4. Transverse section of the male a short distance above the ano-genital cleft. Letters of reference as in fig. 3, with the addition of *n*, *n*, for the two unequal-sized male spicules, and *o*, *o*, the sheaths in which they are contained. The most notable points in this section are the deviation from the cylindrical form, the almost dorsal position of the lateral bands, the strength and bulk of the latero-ventral muscles, and the absence of the ordinary transverse processes, together with the extreme thickening of the walls of the genital tube,

* This figure ought to have followed fig. 9 of the next Plate, and fig. 23 of this Plate should have formed a part of Plate XXV.

and the compression of the alimentary canal with complete obliteration of its cavity.

Fig. 5. Transverse section of one of lateral bands, with neighbouring muscle-cells and integument of *Ascaris lumbricoides* $\frac{3}{4}''$ from the anterior extremity:—*a*, external chitinous layer with transverse markings; *b*, thick homogeneous layer devoid of marking; *c* and *d*, layers with oblique markings in opposite directions; *e*, internal chitinous layer with very delicate longitudinal markings; *f*, cellulo-granular layer of integument; *g*, loose fibrous membrane forming internal boundary of this; *h*, one of nucleated cells found in this layer; *i*, fibrous framework met with in the anterior portion of lateral bands; *k*, transverse section of axial duct or vessel; *l*, contractile tissue of muscle-cell; *m*, contained granular medullary substance; *n*, section through the central part of a small muscle-cell, showing the mode of origin of the bladder-like appendages.

Fig. 6. A portion of one of the lateral ducts removed from the lateral band:—*a*, its lumen; *b*, *b*, adhering nucleated cells of the lateral band.

Fig. 7. A portion of the integument seen from the inner surface, the body of the animal having been slit open and the muscles removed:—*a*, right lateral band; *b*, its axial duct; *c*, *c*, median lines; *d* and *e*, a pair of delicate vessels running through the cellulo-granular layer of integument from median line to median line, and crossing one another in the substance of lateral band.

Fig. 8. One of muscle-cells, lateral aspect:—*a*, contractile portion; *b*, bladder-like development; *c*, transverse muscular prolongations; *d*, nucleus of muscle-cell; *e*, superficial granular material, sometimes containing delicate cells.

Fig. 9. A more elongated muscle-cell, with no bladder-like development seen, but a stronger transverse prolongation.

Fig. 10. Showing the constitution of intestinal wall:—*a*, external structureless membrane; *b*, *b*, two columnar hepatic cells; *c*, very thin internal structureless layer, perhaps formed by a thickening of the cell-wall at this part.

Fig. 11. Tessellated appearance presented by extremities of hepatic cells.

Fig. 12. Floating cells from the general cavity of body of *Ascaris lumbricoides*.

Fig. 13. External transverse markings of the integument of same.

Fig. 14. Portions of the two sets of lamellæ with oblique markings.

Fig. 15. Internal chitinous layer with very fine longitudinal markings.

Fig. 16. Section through anterior part of one of lateral bands and adjacent integument of *Ascaris megalocephala*; references same as in fig. 5. The principal differences are that the band is here absolutely smaller, and the vessel absolutely larger; whilst no fibrous framework exists in the band, whose complete continuity with the deep integumental layer may be well seen.

PLATE XXIV.

Internal aspect of anterior extremity of *Ascaris lumbricoides*, slit open in the mid-dorsal line (œsophagus removed, muscles not represented, lateral bands only in outline). Showing nervous system and so-called "vascular arch," outlined with the camera lucida:—*a*, œsophageal band; *b*, median group of ganglion-cells; *c*, *c*, two submedian ventral groups, the cells of which are mostly bipolar, connected with those of last group and with others, *d*, *d*, imbedded in the substance of the lateral bands; *e*, a large peripheral fibre which was seen to pass in the cellulo-granular layer beneath the muscular bundles; *f*, *f*, nervi submediani; *g*, *g*, nervi laterales; *h*, *h*, very large ganglion(?)-cells; *i*, *i*, bundles of fibres, going to the dorsal head-lobe, chiefly in connexion with the lateral ganglion-cells; *k*, *k*, two distinct bipolar cells on each side; *l*, *l*, lateral ventral head-lobes; *m*, *m*, two halves of dorsal head-lobe; *n*, *n*, lateral bands; *n'*, ventral median line; *o*, "vascular arch"; *p*, large granular cell in substance of wall of vessel on left side; *q*, ventral pore, situated in a plane external to the arch itself, with which it is connected by a single outgoing tube.

PLATE XXV.

Fig. 1. Section through the middle of head-lobes and triangular pharynx of *Ascaris megalocephala*.

Fig. 2. Section of body of same immediately behind the head-lobes:—*a*, chitinous portion of integument; *b*, cellulo-granular layer of same; *c*, *c*, *c*, commencement of longitudinal muscles; *d*, large œsophagus, showing a trilobate form, with thick walls, composed of transverse, radiating fibres, and large, triradiate lumen.

Fig. 3. Section of same slightly anterior to position of nervous ring, showing a blending of prolongations from lateral and median lines around the œsophagus, in which are imbedded the anterior peripheral nerves; letters *a*–*d* same as in last figure; *e*, *e*, lateral bands; *f*, *f*, median lines.

Fig. 4. Section of same (female) just posterior to termination of œsophagus, and anterior to the situation of genital organs; parts similar to those described in Plate XXIII. fig. 2, the most noticeable differences being the smaller size of the lateral band and the greater distinctness of its contained tube, and the alteration in form of the developments from muscle-cells (*h*, *h*)*.

Fig. 5. Section of female of same species through the rectum, slightly anterior to the anal cleft:—*a*, structureless wall of intestine devoid of its cellular lining; *b*, contractile tissue in connexion with the lateral bands, surrounding the intestine like a sphincter, and having imbedded in its substance (*c*, *c*, *c*) one upper, large, and two lower, smaller, densely granular cells, similar to that met with on the left side of vascular arch; *f*, *f*, median lines.

* See also Plate XXIII. fig. 16.

Fig. 6. Section of same through latero-ventral caudal pores:—*a*, chitinous portion of integument; *b*, deep cellulo-glandular portion forming a pretty thick uniform layer; *c*, *c*, caudal pores.

Fig. 7. Section of male *Ascaris megalocephala* a short distance above ano-genital cleft; references same as in Plate XXIII. fig. 4. Principal differences to be noted are the presence of two *equal* male spicules in strong sheaths, the greater thickness of the longitudinal muscle-bands, and the double row of ventral papillæ on each side.

Fig. 8. A large tripolar ganglion-cell seen in substance of left lateral band, anterior to œsophageal ring.

Fig. 9. Exit-tube and arch of excretory vessels with the large granular cell in a thickening of the walls of the left branch; the lumen in this situation is also narrowed, and is often somewhat variable in size in other parts of the vessels.

Fig. 10. Diagrammatic representation of the arrangement and distribution of the transverse vessels contained in the deep cellular layer of a medium-sized *Ascaris megalocephala*, the body having been slit up in the mid-dorsal region, and the viscera with great longitudinal muscles removed:—*a*, right, and *a'*, left lateral band; *b*, ventral median line; *c*, ventral excretory pore; *d*, vulva; *e*, anal cleft.

Fig. 11. Portion of integument of same more highly magnified, showing a pair of transverse vessels, which do not cross one another:—*a*, right lateral band; *b*, its contained vessel; *c*, *c*, median lines; *d*, *d*, thickenings of deep portion of integument on either side of lateral band; *e*, *e*, transverse vessels, which magnified to this extent, appear to be simple lacunar channels running through the substance of cellulo-granular layer in an undulating manner.

Fig. 12. Portion of one of these vessels isolated, and more highly magnified; its walls showing longitudinal fibres and a few intermixed granules.

Fig. 13. Section of muscle-cells and integument of *Ascaris megalocephala*:—*a*, chitinous portion of integument; *b*, cellulo-granular layer; *c*, fibrous aponeurosis bounding same; *d*, contractile portion of muscle-cell; *d'*, contained medullary granular matter; e^1–e^6, sections through different portions of muscle-cells, from narrow closed extremities to wide median portions, from which the transverse prolongations (*f*, *f*) are given off.

*Fig. 14. Transverse section of *Dracunculus medinensis*:—*a*, chitinous portion of integument; *b*, deep cellulo-granular layer not presenting the usual lateral bands, though the muscular interspaces are unusually wide; *c*, bounding wall of greatly developed uterine sac; *d*, compressed intestine; *e*, *e*, space occupied by dorsal muscles; *e'*, *e'*, ditto by ventral.

*Fig. 15. Glandular portion of one of muscle-cells of same separated and highly magnified, showing its internal loculated structure and central nucleus.

* These two figures should have formed part of Plate XXVII., with the others (figs. 20–24) illustrative of the anatomy of *Dracunculus medinensis*.

PLATE XXVI.

Fig. 1. Transverse section of the anterior extremity of *Ascaris marginata* through its œsophageal (nervous) ring:—*a*, *a*, lines seen in chitinous portion of integument; *b*, *b*, *b*, *b*, the four principal communications of muscles with sheath of œsophageal ring; *c*, *c*, ganglion-cells in substance of ring.

Fig. 2. Section of same slightly posterior to arch of excretory vessels:—*a*, *a*, unequal-sized lateral bands; *b*, *b*, unequal-sized axial vessels; *c*, œsophagus; *d*, anterior intestinal cæcum; *e*, *e*, space occupied by dorsal muscles; *f*, *f*, ditto by ventral.

Fig. 3. Section of three muscle-cells of same species.

Fig. 4. Transverse section of anterior extremity of *Ascaris mystax*, slightly posterior to arch of excretory vessels:—*a*, *a*, lateral integumental alæ; *b*, œsophagus; *c*, *c*, space occupied by dorsal muscles; *d*, *d*, ditto, by ventral; *e*, *e*, narrow projections of chitinous layer into substance of lateral bands; *f*, *f*, axial vessels.

Fig. 5. Transverse section of intestinal canal of the same:—*a*, thick internal structureless cuticle; *b*, columnar hepatic cells; *d*, thin external structureless membrane.

Fig. 6. Anterior half of body of *Ascaris osculata*, slit up in dorsal region ($\times 3$), showing position and nature of so-called "lemniscus," developed from left lateral band (*a*) and the course of the main excretory canal (*b*) which communicates with the exterior at *c*:—*d*, right lateral band.

Fig. 7. Portion of the lemniscus from the situation indicated by *e* in last figure, more highly magnified:—*a*, portion of the main excretory vessel, from which are given off innumerable, inosculating, thin-walled branches, in the middle of the delicate cellulo-granular material of which this development is composed.

Fig. 8. Showing the narrow termination of the lemniscus (*a*) on the side of the bilobed lateral band (*b*), and also the gradual termination of the main excretory vessel (*c*).

Fig. 9. Transverse section of anterior extremity of *Ascaris osculata*, through the lateral cervical pores (*a*, *a*), showing the very unequal size in this region of the two bilobed lateral bands (*b*, *b*), and the single vessel (*c*), just as it is about to leave the large lower lobe of the left band in order to reach the mid-ventral pore. The intestinal cæcum does not reach so far forward as the situation of this section.

Fig. 10. Transverse section of the body of *Ascaris osculata*, slightly posterior to termination of œsophagus:—*a*, intestinal canal with extremely thick glandular walls; *b*, *b*, bilobed lateral bands, nearly equal in size; *c*, lemniscus projecting from the lower lobe of left band across the ventral region of the body, its free extremity being connected by some delicate fibro-cellular tissue with the

lower lobe of right band; *d*, main vessel from which branches indicated by dark lines are given off; *e*, central cavity of lemniscus; *f*, *f*, space occupied by dorsal muscles; *f'*, *f'*, ditto by ventral; *g*, cellulo-granular layer of integument, having no developments in mid-dorsal and ventral region; *h*, chitinous portion of integument.

Fig. 11. Transverse section of anterior extremity of same, in the situation of its central nervous system. Parts same as in fig. 1, except *a*, which here represents the anterior excretory duct slightly posterior to its point of communication with the exterior, near the bases of the two ventral head-lobes.

Fig. 12. Transverse section of the posterior extremity of the male of same species, just above ano-genital cleft. References same as in Plate XXIII. fig. 4, and Plate XXV. fig. 7. The most notable points are the extreme size of the latero-ventral muscular bands (*k*, *k*), and the entire obliteration of the lateral lines. The two dorsal muscles appear as one band only, equalling in size each one of the widely separated ventral muscles, which are now more lateral in position.

Fig. 13. Transverse section through œsophageal region of *Ascaris spiculigera*:—*a*, *a*, lateral bands, each having a horizontal fibrous septum; *b*, anterior portion of lemniscus, with its axial vessel and radiating branches; *c*, œsophagus; *d*, anterior intestinal cæcum; *e*, coagulated material, containing small cells or granules, in general cavity of body.

Fig. 14. Transverse section of same near the middle of lemniscus, showing its connexion with the lateral bands, as in fig. 10. In this species the lemniscus is thicker, contains only a very small central cavity, and the main excretory vessel occupies its axis, giving off inosculating branches on all sides.

Fig. 15. Section of same, nearly opposite the posterior termination of lemniscus:—*a*, the very thick chitinous portion of the integument; *b*, lemniscus near its termination, still showing axial vessel.

Fig. 16. Middle portion of lemniscus of *Ascaris spiculigera*, showing its small, broadly fiddle-shaped central cavity, and deviation of central vessel from its axial position.

Fig. 17. External layer of integument of same.

Fig. 18. Integument of same, more deeply focused.

Fig. 19. Section through the middle of the body of a female *Spiroptera obtusa*, showing the extreme inequality in the size of lateral bands (*a*, *a*):—*b*, *b*, median lines; *c*, intestinal canal; *d*, *d*, two ovarian tubes.

Fig. 20. Section close to anterior extremity of same, showing a ventral communication between the lateral bands, though no axial vessel could be detected.

Fig. 21. Section of muscle-cells and integument of same species:—*a*, thick chitinous portion of integument; *b*, very thin cellulo-granular layer; *c*, contractile portion of muscle-cell; *d*, medullary and bladder-like portion.

Fig. 22. Transverse section of a female specimen of *Filaria*, from the subcutaneous tissue of a water-bird:—*a*, *a*, rather broad, flattened lateral bands, in which no vessels could be detected; *b*, intestine; *c*, *c*, *c*, three oviducts filled with ova; *d*, three narrower extremities of same ovarian tubes.

PLATE XXVII.

Fig. 1. Anterior extremity of *Prothecosacter inflexus*, dorsal aspect:—*a*, œsophagus; *b*, *b*, lateral cervical pores; *c*, *c*, lateral bands.

Fig. 2. Posterior extremity of female specimen of same, ventral aspect:—*a*, *a*, latero-ventral caudal pores; *b*, *b*, terminations of lateral bands.

Fig. 3. Anterior extremity of same, lateral aspect:—*a*, triangular mouth in centre of somewhat flattened circular space; *b*, mid-ventral pore with an infundibuliform opening; *c*, right lateral band; *d*, process given off from same to ventral pore, in which, however, no vessel could be detected.

Fig. 4. Transverse section of same slightly posterior to the termination of œsophagus:—*a*, *a*, lateral band; *b*, *b*, almost imperceptible median lines; *b'*, *b'*, *b'*, *b'*, equally indistinct accessory longitudinal lines; *c*, *c*, intestinal canal held in position by fibrous processes; *e*, *e*, surface projections of integument corresponding with superficial markings.

Fig. 5. Transverse section of muscle-cells and integument of same, showing:—*a*, thick homogeneous chitinous portion of integument; *b*, very thin cellulo-granular layer of same; *c*, deep and very narrow muscular elements.

Fig. 6. Highly refractive particles filling the anterior part of general cavity of body of some specimens.

Fig. 7. Portion of integument, showing nature of its surface-markings due to ridges or minute elevations.

Fig. 8. Lateral aspect of anterior extremity of *Strongylus filaria*, with the two ventral glands (*a*) dissected out, and showing the manner in which they are connected with the single median pore.

Fig. 9. Posterior extremity of same:—*a*, lateral band; *b*, *b*, caudal pores here upper and lower instead of lateral; *c*, anal cleft.

Fig. 10. Portion of integument of a red-coloured *Strongylus* from the stomach of a Hare, showing its longitudinal and transverse markings.

Fig. 11. Anterior extremity of *Cucullanus heterochrous* (*Dacnitis esuriens*, Duj.), lateral aspect:—*a*, mid-ventral pore; *b*, sac in connexion with same; *c*, *d*, anterior and posterior branches on left side in connexion with sac, in which are seen molecules suspended in a clear fluid; anterior branch terminating cæcally opposite pharynx (*e*); *f*, œsophagus; *g*, intestine; *h*, fibrous band (probably nervous) surrounding œsophagus in this situation.

Fig. 12. Posterior extremity of same:—*a*, cæcal termination of posterior branch; *b*, left lateral caudal pore; *c*, anal cleft.

Fig. 13. Transverse section through body of same species in œsophageal region:—*a*, *a*, lateral bands; *b*, *b*, large axial vessels; *c*, œsophagus; *d*, *d*, thickenings of lining membrane forming longitudinal bands; *e*, *e*, muscle-cells.

Fig. 14. Lateral aspect of portion of *Trichosoma longicolle*:—*a*, *a*, segmented œsophagus; *b*, small lumen of same; *c*, one of œsophageal appendages; *d*, intestine; *e*, *e*, ova, within oviduct; *f*, *f*, integumental pores over situation of mid-ventral cellular band (*g*); *h*, mid-dorsal band.

Fig. 15. Magnified representation of integument in the situation of the peculiar dorsal band of *Trichocephalus dispar*.

Fig. 16. Portion of same near its termination, showing the integumental channels under different aspects—on the right-hand side they are seen as when looked down upon in the direction of their length, and on the left hand in intermediate positions between this and a direction at right angles to it.

Fig. 17. Portion of integument over and adjoining dorsal band of *Trichocephalus affinis*, showing, as in fig. 15, the cessation of transverse markings at border of band.

Fig. 18. Transverse section of same through anterior part of œsophageal region of body, showing the broad dorsal band consisting of integumental channels in connexion with a subjacent loculated cellular structure; no muscles covering this band internally, and nearly the whole of cavity of body occupied by the œsophagus, with narrow central lumen and thick cellular parietes.

Fig. 19. Portion of posterior part of œsophagus of same.

Fig. 20. Caudal extremity of adult *Dracunculus medinensis*:—*a*, anus; *b*, intestine; *c*, right lateral caudal pore*.

Fig. 21. Portion of integument with one of caudal pores, more highly magnified.

Fig. 22. Posterior extremity of young Guineaworm:—*a*, anus; *b*, intestine; *c*, right lateral caudal pore; *d*, outline of internal sac in connexion with same.

Fig. 23. Dorsal aspect of lateral caudal pores of same, with their attached sacculi.

Fig. 24. Lateral aspect of anterior extremity of young Guineaworm, showing (*a*) a rudimentary mid-ventral pore.

Free Nematoids.

PLATE XXVIII.

Fig. 1. Female *Dorylaimus stagnalis*.

Fig. 2. Male of same species.

Fig. 3. Anterior extremity of same species more highly magnified, ventral aspect:—*a*, *a*, deciduous portion of spear; *b*, central framework through which it

* In Plate XXV. figs. 14 & 15, other points in the anatomy of this animal are illustrated.

moves; *c*, permanent rigid shaft of spear; *d*, permanent spear itself lodged in substance of wall of œsophagus; *e*, *e*, two longitudinal contractile bands destined to move anterior portion of œsophagus and protrude spear; *f*, *f*, retinacula, binding these bands to parietal muscles; *h*, *h*, integumental pores.

Fig. 4. Portion of posterior extremity of same opposite the region where intestinal canal becomes narrowed (*a*):—*b*, *b*, thick chitinous portion of integument; *c*, *c*, lateral integumental channels through same; *d*, *d*, lateral bands seen in outline.

Fig. 5. Portion of œsophagus of same:—*a*, lumen; *b*, *b*, hyaline cells from œsophageal walls.

Fig. 6. Four of hepatic cells from walls of intestine of same, showing granular contents only, in the form of dark-coloured, highly-refractive particles.

Fig. 7. Group of glandular cells from surface of muscles of same.

Fig. 8. Three spermatic cells of same as they are most frequently seen.

Fig. 9. Later stage of same, more rarely met with, in form of elongated spindle-shaped filaments.

Fig. 10. Two hepatic cells of *Dorylaimus muscorum*, showing in each a homogeneous, central, nuclear body in addition to light-coloured particles.

Fig. 11. Terminal portion of œsophagus of *Rhabditis marina*, showing simple valvular apparatus closed.

Fig. 12. Same, valvular apparatus open.

Fig. 13. Motory spermatozoa of same species.

Fig. 14. Anterior extremity of *Plectus parietinus* highly magnified, ventral aspect:—*a*, *a*, lateral, circular, integumental spaces, probably having minute central apertures in communication with transparent flexuous vessels (*b*, *b*) by means of narrower and more rigid portions (*b′*, *b′*); *c*, mid-ventral pore in connexion with *d*, the curved, twisted and somewhat rigid duct in connexion with gland.

Fig. 15. One uterine segment and ovarian tube of same species:—*a*, vulva; *b*, uterus filled with large spermatic (?) cells; *c*, *c*, short thick ovarian tube containing unimpregnated ova.

Fig. 16. Bodies almost exactly resembling the spermatic corpuscles of fig. 27, though smaller, which were found filling the whole cavity of the body of a specimen of *Plectus cirrhatus*.

Fig. 17. Anterior extremity of adult *Tylenchus* (*Vibrio*) *tritici*, lateral aspect:—*a*, mid-ventral pore, communicating with curved rigid duct (*b*); *c*, one of lateral flexuous vessels; *d*, pharyngeal spear; *e*, mid-œsophageal muscular swelling.

Fig. 18. Spermatozoa of same species in different stages of development.

Fig. 19. Hyaline cells, such as completely fill all otherwise unoccupied parts of the cavity of the body of same species.

Fig. 20. Ventral gland of *Tylenchus Davainii*:—*a*, its distinct rigid duct; *b*, very indistinct terminal dilated portion.

Fig. 21. Minute granular cells, which were found distending the cavity of the body in a specimen of same species. See fig. 16 also.

Fig. 22. Minute almost granular spermatozoa of *Theristus acer*.

Fig. 23. Spermatozoa of *Comesoma vulgaris*.

Fig. 24. Large ovoid spermatic cells of *Monhystera vulgaris*.

Fig. 25. Small ovoid spermatozoa of *Enoplus communis*.

Fig. 26. Motory spermatic filaments of *Monhystera disjuncta*.

Fig. 27. Spermatozoa of an undescribed marine species.

Fig. 28. Portion of intestine of *Aphelenchus parietinus*, showing the indistinct granular aspect of its cellular layer, with a very distinct internal bounding membrane.

Fig. 29. A group of hepatic cells from intestine of *Oncholaimus attenuatus*, showing the very large size of homogeneous central nuclear bodies, the granules forming a lining superficial to these.

Fig. 30. Floating gland-cells from general cavity of body of same.

Fig. 31. Much larger cells with central nucleus from general cavity of body of *Leptosomatum figuratum*.

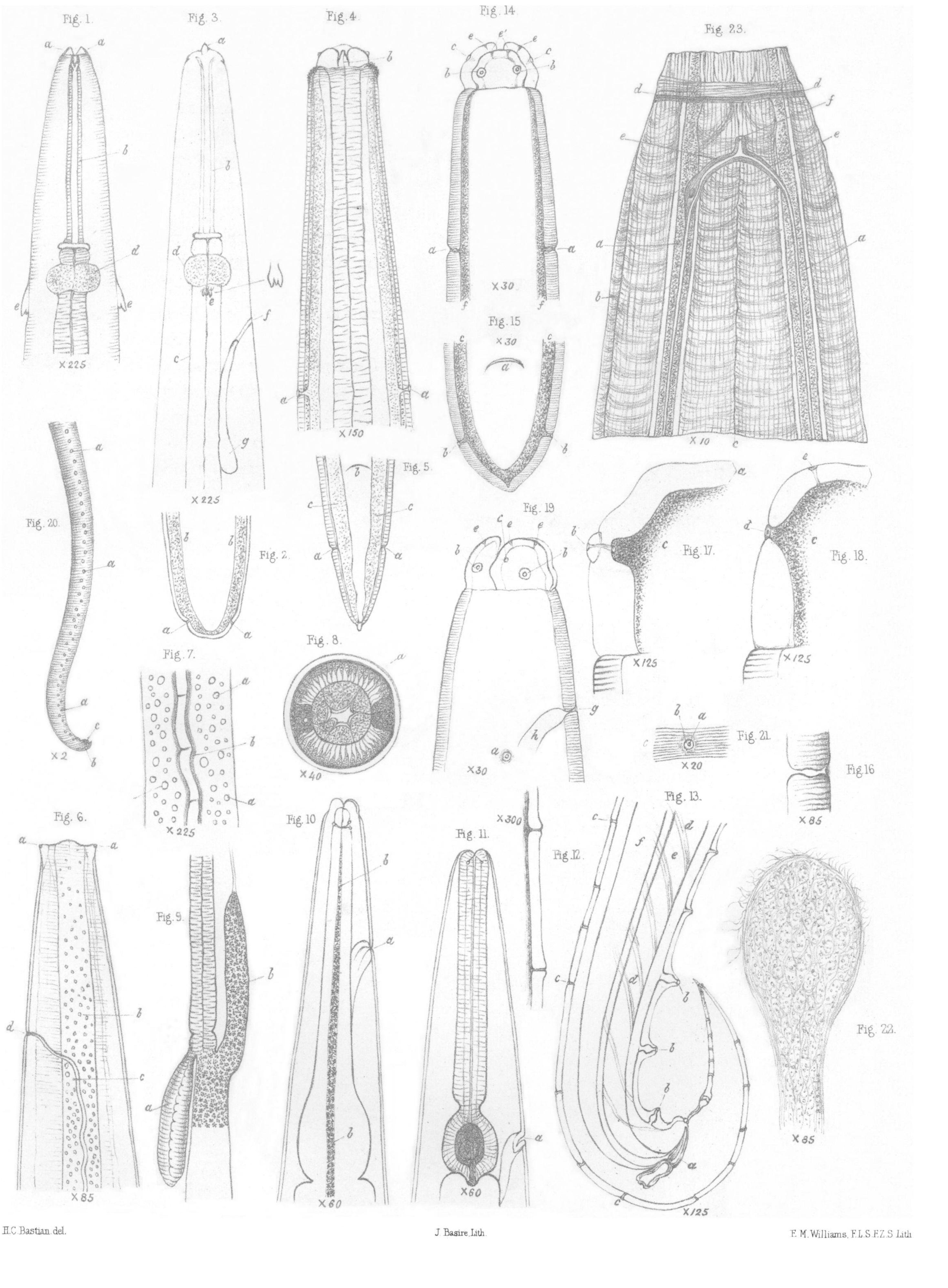
Fig. 32. Glandular layer and processes from surface of longitudinal muscles of *Symplocostoma longicolle*:—*a*, mass lying on surface of muscle (*b*); *c*, *c*, *c*, pedunculated growths from same, each containing in addition to finely granular matter, a central homogeneous body or nucleus ("vacuole"); *d*, secondary growth of same kind connected by very narrow peduncle with primary; *e*, one of these bodies with its pedicle torn seen floating freely in cavity of body.

Fig. 33. Anterior extremity of *Leptosomatum figuratum*, showing:—*a*, *a*, ocelli on dorsal aspect of œsophagus, each containing a rounded lens, imbedded anteriorly; *b*, œsophageal ring of uncertain nature; *c*, *c*, integumental pores in connexion with the lateral bands (*d*, *d*).

Fig. 34. Portion of lateral band of same species showing a distinctly cellular structure.

Fig. 35. Simple granular appearance of lateral band *Linhomœus hirsutus*.

Fig. 36. Anterior extremity of *Cyatholaimus ornatus*, lateral aspect:—*a*, tubular ventral gland; *b*, cup-shaped pharyngeal cavity; *c*, single dorsal ocellus; *d*, *d*, cells of deep cutaneous layer (?).



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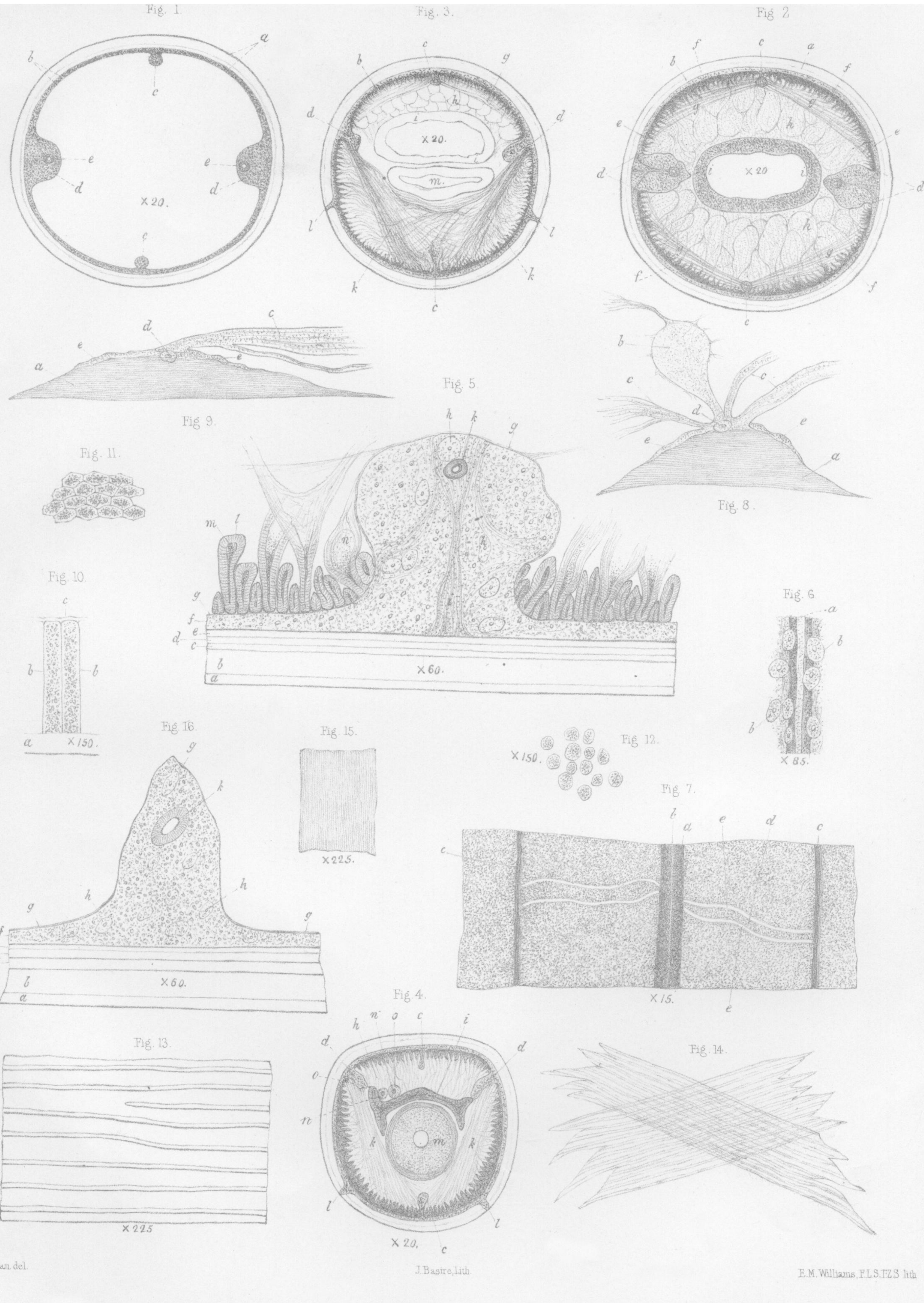
Anatomy of Nematoids, Parasitic and Free.



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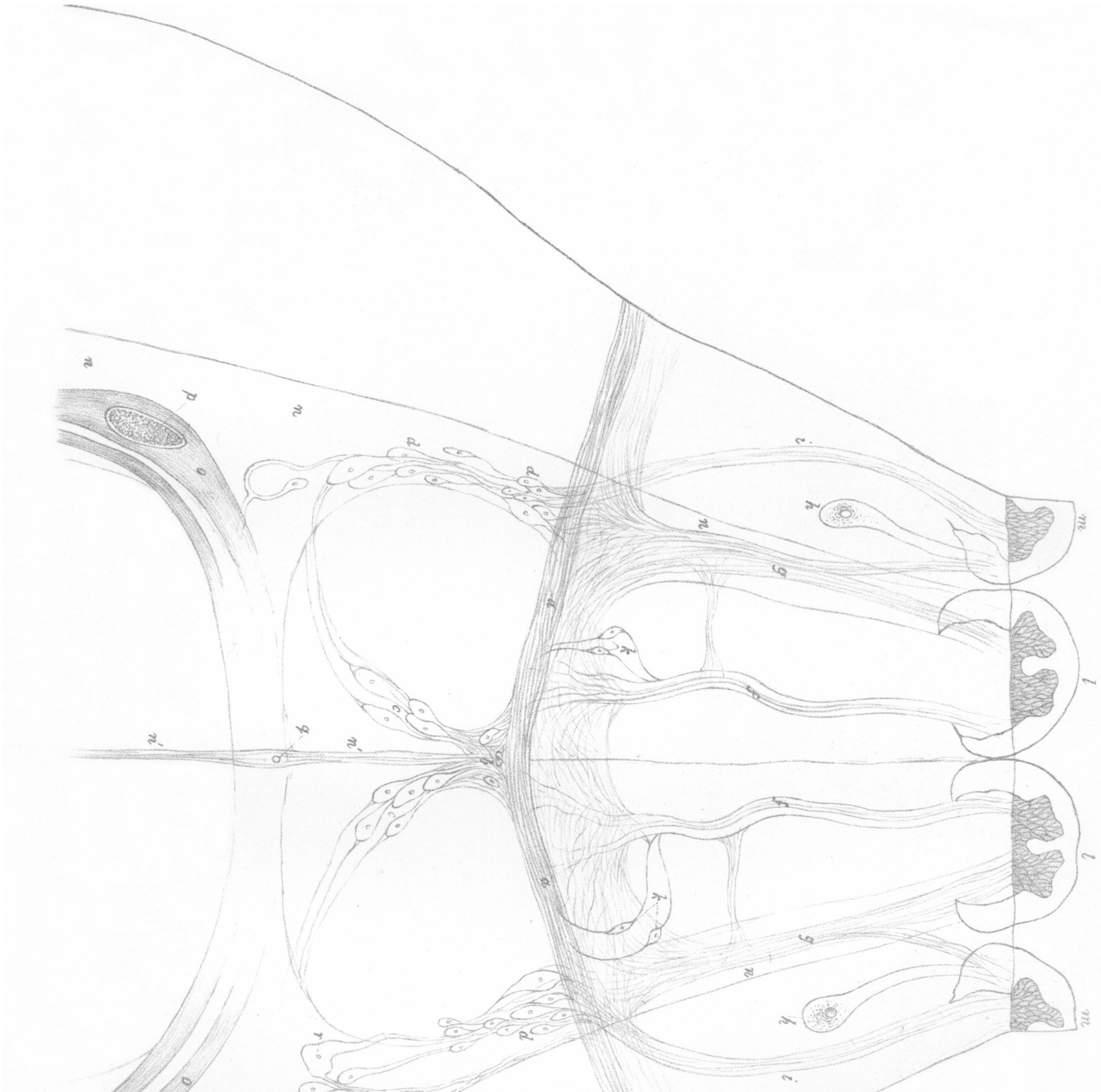

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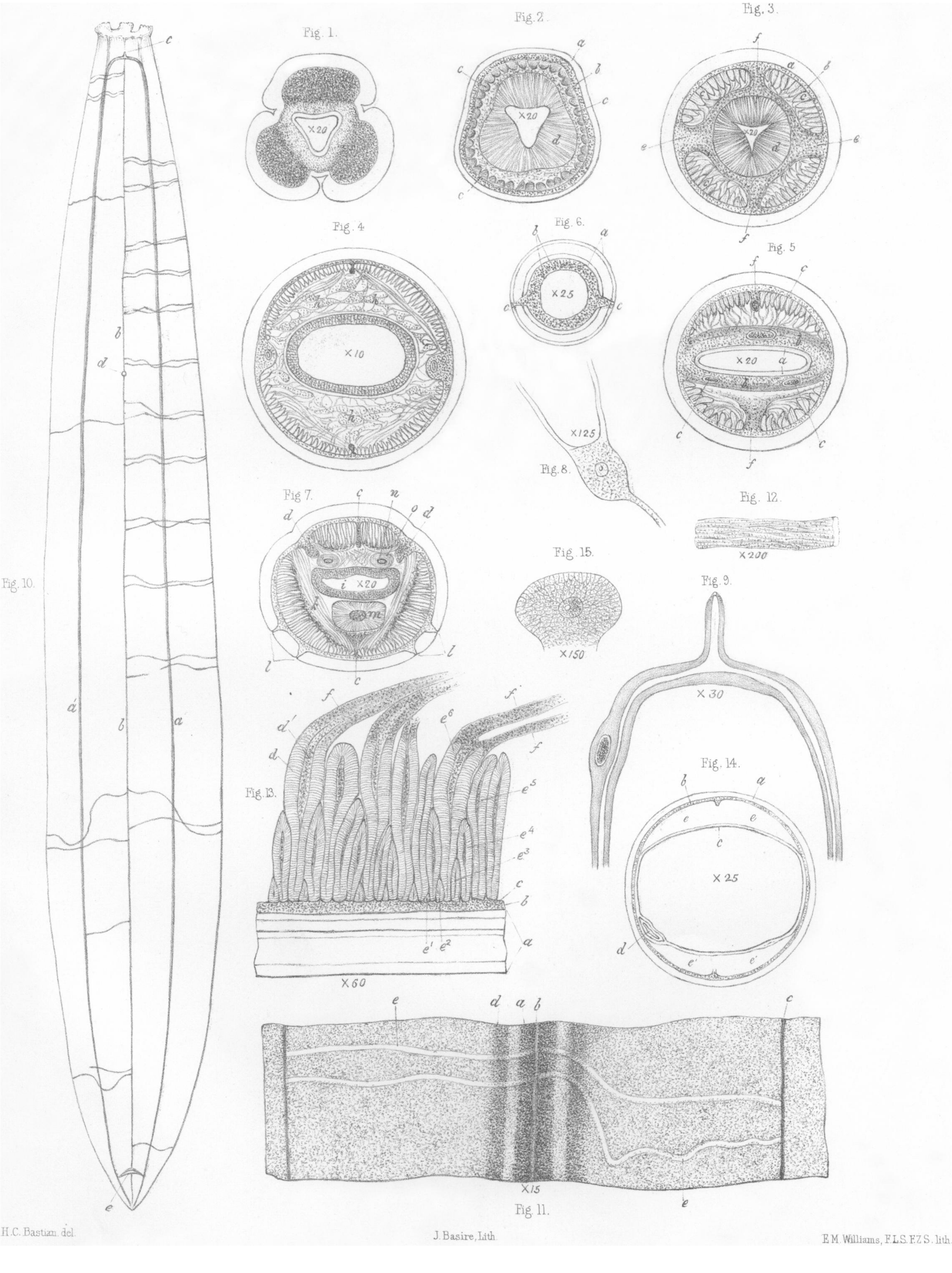

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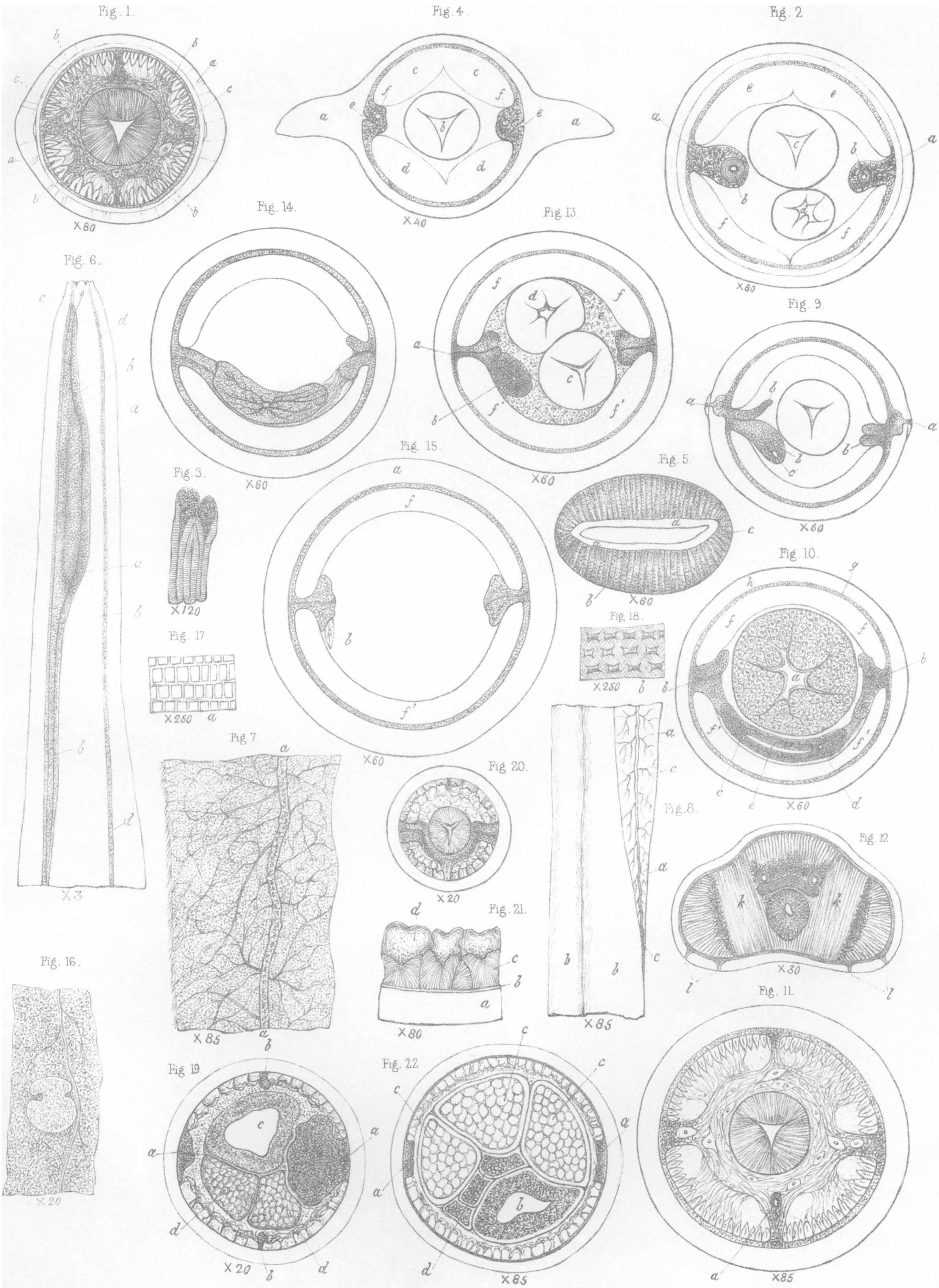

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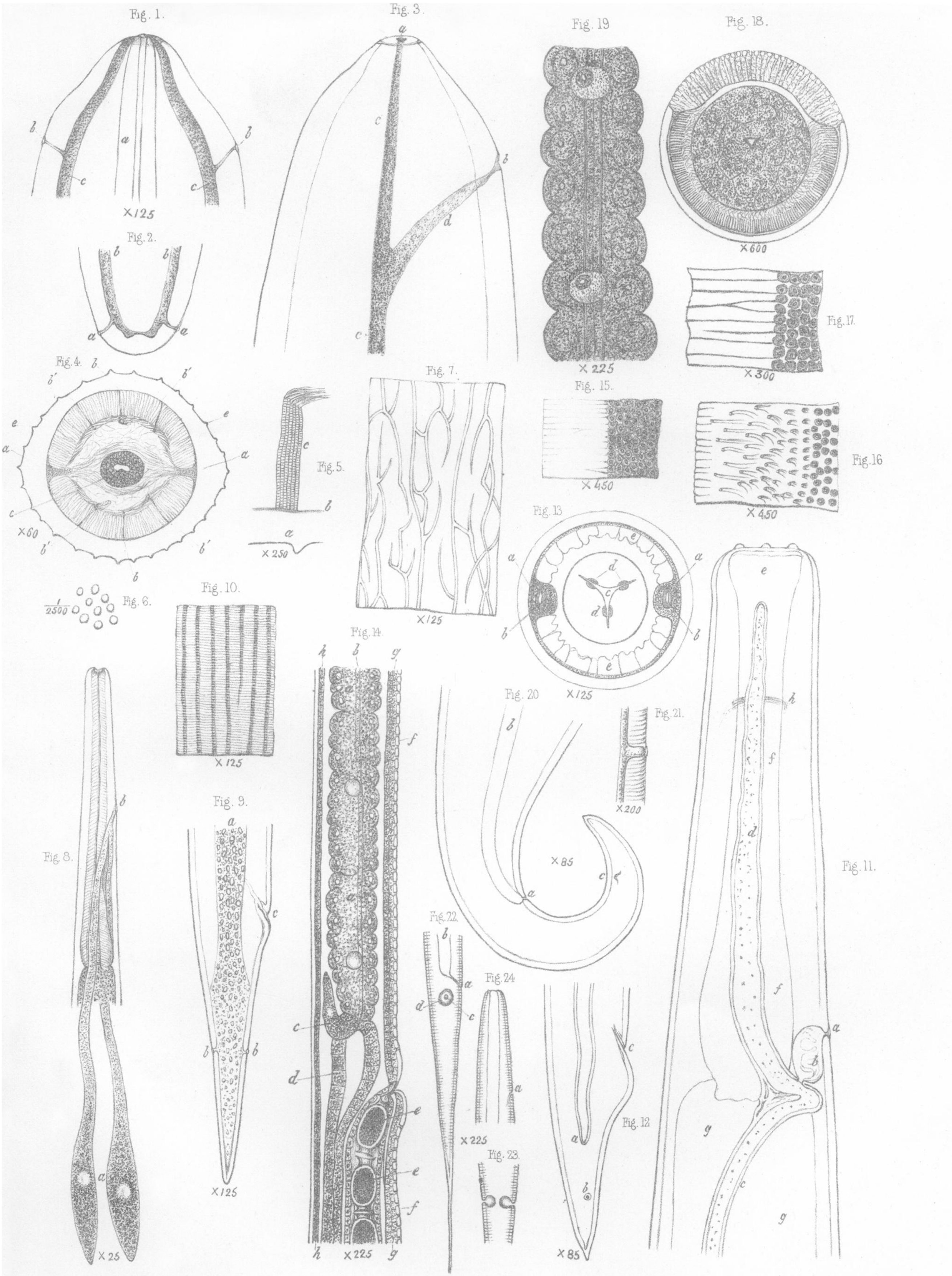

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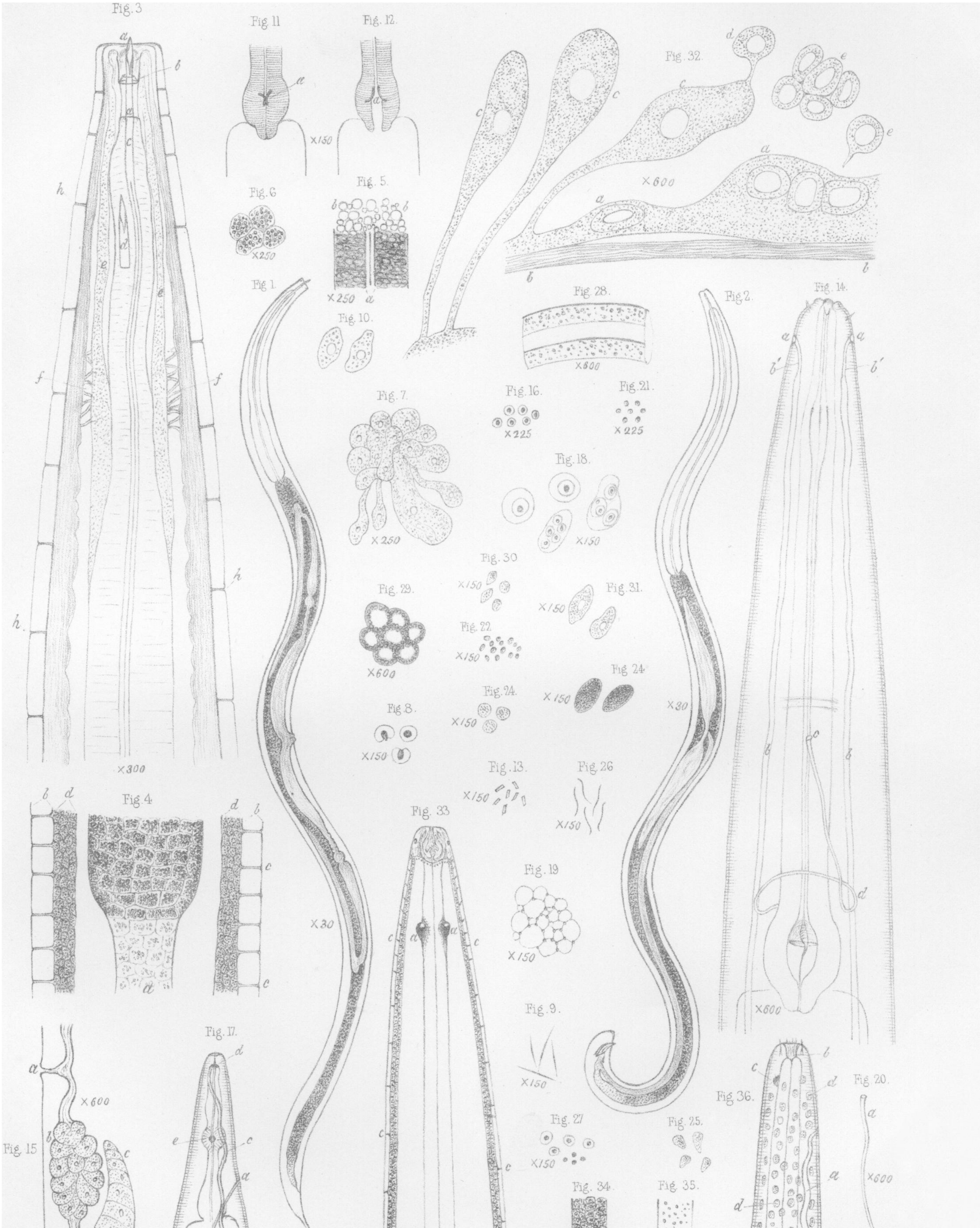

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